

## Section 2

### ASSESSMENT OF THE PACIFIC COD STOCK IN THE EASTERN BERING SEA AND ALEUTIAN ISLANDS AREA

Grant G. Thompson and Martin W. Dorn

#### EXECUTIVE SUMMARY

##### Summary of Major Changes

Relative to the November edition of last year's BSAI SAFE report, the following substantive changes have been made in the Pacific cod stock assessment.

##### Changes in the Input Data

- 1) Size composition data from the 2000 and January-August 2001 commercial fisheries were incorporated into the model.
- 2) Size composition data from the 2001 EBS bottom trawl survey were incorporated.
- 3) The biomass estimate from the 2001 EBS bottom trawl survey was incorporated (the 2001 estimate of 830,479 t was up about 57% from the 2000 estimate).

##### Changes in the Assessment Model

The Bayesian meta-analysis which has formed the basis for a risk-averse ABC recommendation in the 1996-1999 assessments was not performed for the present assessment. Similar to last year's approach, the ratio between the recommended  $F_{ABC}$  and  $F_{40\%}$  estimate given in the 1999 assessment (0.87) was assumed to be an appropriate factor by which to multiply the 2001 maximum permissible  $F_{ABC}$  to obtain a recommended 2001  $F_{ABC}$ .

##### Changes in Assessment Results

- 1) The estimated 2002 spawning biomass for the BSAI stock is 425,000 t, up about 15% from last year's estimate for 2001 and up about 25% from last year's  $F_{ABC}$  projection for 2002.
- 2) The estimated 2002 total age 3+ biomass for the BSAI stock is 1,540,000 t, up about 17% from last year's estimate for 2001 and up about 33% from last year's  $F_{40\%}$  projection for 2002.
- 3) The recommended 2002 ABC for the BSAI stock is 223,000 t, up about 19% from last year's recommendation for 2001 and up about 45% from last year's  $F_{ABC}$  projection for 2002.
- 4) The estimated 2002 OFL for the BSAI stock is 294,000 t, up about 19% from last year's estimate for 2001.

## Responses to Comments of the Scientific and Statistical Committee (SSC)

### SSC Comments Specific to the Pacific Cod Assessments

From the December, 2000 minutes: *“The SSC recommends that a stock recruitment relationship be included in the next assessment and that the age composition of the adult spawning stock be assessed relative to recruitment levels, because other cod stocks (in the Atlantic) have shown that the occurrence of strong year classes is dependent on the presence of a broad age distribution in the spawning stock.”* A provisional stock-recruitment relationship is described, with appropriate caveats, in the “Recruitment” subsection of the “Results” section.

From the December, 2000 minutes: *“Pacific cod is of special concern for precautionary measures in the setting of the ABC. That is not only because of the declining spawning biomass, but also because of the possibility of unknown fishery sampling inadequacy. Sampling is being reviewed currently by the Observer Program. The SSC expressed its concern more completely in last year’s minutes, especially from the October 1999 meeting. Sampling the Pacific fishery is difficult because of the complexity of its various fishing sectors.”* A precautionary ABC is recommended in the “ABC recommendation” subsection of the “Projections and Harvest Alternatives” section.

### SSC Comments on Assessments in General

From the December, 2000 minutes: *“The unprecedented demands on the analysts related to SEIS and SSL issues resulted in less time and attention being devoted to stock assessments this year. It is ironic that with the increased scrutiny of the Council’s management of groundfish, that one of the main responsibilities of the Council, the TAC-setting process, is being compromised to some extent. It is imperative that analysts serving the Council process be allowed to devote sufficient time and energy to produce quality stock assessments.”* The time available for development of improved stock assessment methodologies was much greater this year.

From the December, 2000 minutes: *“Similarly, the consideration of new ABC and OFL definitions has been put on hold pending the freeing up of analysts’ time. The SSC hopes that this issue can proceed in the year 2001 to assure that the Council’s TAC-setting is based on solid conservation standards.”* Some progress has been made this year in the evaluation of alternative harvest strategies, though a full analysis of the ABC and OFL definitions has not been made.

From the December, 2000 minutes: *“The issue of adjusting ABC based on uncertainties in data and information came up this year in the BSAI Atka mackerel assessment. While the SSC did not approve of the approach used, the SSC encourages further exploration of this issue. As the methodology evolves to constructing ADMB age-structured assessment models for most assessments, it is possible that formal definitions of risk to the population and to the fishery can be developed that conceivably would lead to greater downward adjustments when uncertainty is higher.”* Some progress has been made this year in developing adjustments to the maximum permissible ABC based on formal definitions of risk.

From the December, 2000 minutes: *“The SSC heard that the 2001 survey in the Gulf of Alaska may only be a partial survey excluding the eastern Gulf. For some stock assessments, this could create major problems in using the survey information in the assessment, because of incomplete sampling of the population. The SSC hopes that a complete survey can be conducted.”* Pacific cod is relatively rare in the eastern GOA, accounting for only 2-7% of the total biomass estimated by the three previous surveys. The Pacific cod

chapter of the GOA SAFE report describes the method used in that assessment to adjust for the missing stations.

## INTRODUCTION

Pacific cod (*Gadus macrocephalus*) is a transoceanic species, occurring at depths from shoreline to 500 m. The southern limit of the species' distribution is about 34° N latitude, with a northern limit of about 63° N latitude. Pacific cod is distributed widely over the eastern Bering Sea (EBS) as well as in the Aleutian Islands (AI) area. The resource in these two areas (BSAI) is managed as a single unit. Tagging studies (e.g., Shimada and Kimura 1994) have demonstrated significant migration both within and between the EBS, AI, and Gulf of Alaska (GOA), and genetic studies (e.g., Grant et al. 1987) have failed to show significant evidence of stock structure within these areas. Pacific cod is not known to exhibit any special life history characteristics that would require it to be assessed or managed differently from other groundfish stocks in the EBS or AI areas.

## FISHERY

During the early 1960s, a Japanese longline fishery harvested BSAI Pacific cod for the frozen fish market. Beginning in 1964, the Japanese trawl fishery for walleye pollock (*Theragra chalcogramma*) expanded and cod became an important bycatch species and an occasional target species when high concentrations were detected during pollock operations. By the time that the Magnuson Fishery Conservation and Management Act went into effect in 1977, foreign catches of Pacific cod had consistently been in the 30,000-70,000 t range for a full decade. Catches of Pacific cod since 1978 are shown in Table 2.1, broken down by management area, year, fleet sector, and gear type. In 1981, a U.S. domestic trawl fishery and several joint venture fisheries began operations in the BSAI. The foreign and joint venture sectors dominated catches through 1988, but by 1989 the domestic sector was dominant and by 1991 the foreign and joint venture sectors had been displaced entirely. Presently, the Pacific cod stock is exploited by a multiple-gear fishery, including trawl, longline, pot, and jig components.

The history of acceptable biological catch (ABC) and total allowable catch (TAC) levels is summarized and compared with the time series of aggregate (i.e., all-gear, combined area) commercial catches in Table 2.2. From 1980 through 2001, TAC averaged about 75% of ABC, and aggregate commercial catch (excluding 2001, for which a final catch total is not yet available) averaged about 87% of TAC. In 8 of these 22 years (36%), TAC equaled ABC exactly, and in 4 of these 22 years (18%), catch exceeded TAC. Changes in ABC over time are typically attributable to three factors: 1) changes in resource abundance, 2) changes in management strategy, and 3) changes in the stock assessment model. For example, from 1980 through 2000, five different assessment models were used (Table 2.2), though the present model has remained unchanged since 1997.

Historically, the great majority of the BSAI catch has come from the EBS area. During the most recent five-year period (1996-2000), the EBS accounted for an average of about 85% of the BSAI catch. The distribution of federally observed hauls or sets in the BSAI is shown for the 2000 trawl, longline, and pot fisheries for Pacific cod in Figures 2.1, 2.2, and 2.3, and for the 2001 trawl, longline, and pot fisheries for Pacific cod in Figures 2.4, 2.5, and 2.6.

The catches shown in Tables 2.1 and 2.2 include estimated discards. Recent (2000-2001) discard rates of Pacific cod in the various BSAI target fisheries are summarized in Table 2.3. In terms of absolute amounts, the target fishery for Pacific cod had a higher level of Pacific cod discards than any other fishery in both years. Expressed in relative terms, however, the target fishery for Pacific cod had below-average rates of Pacific cod discards in both years. The target fishery defined as "no retained groundfish" had the highest

relative discard rate for Pacific cod in both years, followed by the target fishery for sablefish.

For the 2001 fishery, several new regulations were adopted in an attempt to mitigate possible fishery impacts on the endangered western population of Steller sea lion (*Eumetopias jubatus*). Some of these regulations were designed to spread the catch of Pacific cod more evenly throughout the year. The table below compares the distribution of catch during the periods January-May and June-August for the 2001 fishery with the average for the preceding three years (for each gear type, the numbers in a given row sum to 1.0):

| <u>Area</u> | <u>Year(s)</u> | Trawl          |                | Longline       |                | Pot            |                |
|-------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
|             |                | <u>Jan-May</u> | <u>Jun-Aug</u> | <u>Jan-May</u> | <u>Jun-Aug</u> | <u>Jan-May</u> | <u>Jun-Aug</u> |
| BS          | 2001           | 0.76           | 0.24           | 0.85           | 0.15           | 0.96           | 0.04           |
| BS          | 1998-2000      | 0.91           | 0.09           | 0.98           | 0.02           | 0.90           | 0.10           |
| AI          | 2001           | 0.97           | 0.03           | 0.88           | 0.12           | 1.00           | 0.00           |
| AI          | 1998-2001      | 0.98           | 0.02           | 0.97           | 0.03           | 0.96           | 0.04           |

Because year-end catch statistics for 2001 are not yet available, the above table provides only a partial indication of the extent to which the new regulations were or will be successful in spreading the 2001 catch evenly throughout the entire year.

## DATA

This section describes data used in the current assessment. It does not attempt to summarize all available data pertaining to Pacific cod in the BSAI.

### Commercial Catch Data

#### Catch Biomass

Catches (including estimated discards) taken in the EBS since 1978 are shown in Table 2.4, broken down by the three main gear types and the following within-year time intervals, or “periods”: January-May, June-August, and September-December. This particular division, which was suggested by participants in the EBS fishery, is intended to reflect actual intra-annual differences in fleet operation (e.g., fishing operations during the spawning period may be different than at other times of year). In years for which estimates of the distribution by gear or period were not available, proxies based on other years’ distributions were used.

#### Catch Size Composition

Fishery size compositions are presently available, by gear, for the years 1978 through the first part of 2001. As in all assessments since 1997, size composition data from trawl catches sampled on shore were not included in the set of input data, because a comparison of cruises for which both at-sea and shoreside size composition samples were available showed that, in the case of trawl catches, the shoreside data typically contained a smaller proportion of small fish than the at-sea data, indicating that these data may reflect post-discard landings rather than the entire catch. For ease of representation and analysis, length frequency data for Pacific cod can usefully be grouped according to the following set of 25 intervals or “bins,” with the upper and lower boundaries shown in cm:

|              |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |     |     |
|--------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|-----|-----|
| Bin Number:  | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24  | 25  |
| Lower Bound: | 9  | 12 | 15 | 18 | 21 | 24 | 27 | 30 | 33 | 36 | 39 | 42 | 45 | 50 | 55 | 60 | 65 | 70 | 75 | 80 | 85 | 90 | 95 | 100 | 105 |
| Upper Bound: | 11 | 14 | 17 | 20 | 23 | 26 | 29 | 32 | 35 | 38 | 41 | 44 | 49 | 54 | 59 | 64 | 69 | 74 | 79 | 84 | 89 | 94 | 99 | 104 | 115 |

Total length sample sizes for each year, gear, and period are shown in Table 2.5. The collections of relative length frequencies are shown by year, period, and size bin for the pre-1989 trawl fishery in Table 2.6, the pre-1989 longline fishery in Table 2.7, the post-1988 trawl fishery in Table 2.8, the post-1988 longline fishery in Table 2.9, and the pot fishery in Table 2.10.

## Survey Data

### EBS Shelf Trawl Survey

The relative size compositions from trawl surveys of the EBS shelf conducted by the Alaska Fisheries Science Center since 1979 are shown in Table 2.11, using the same length bins defined above for the commercial catch size compositions. Information regarding the absolute numbers of fish measured at each length are available only for the years 1986-1987 and 1990-2001. For all other years, only relative numbers of measured fish are available. The total sample sizes from the years 1986-1987 and 1990-2001 are shown below:

|              |       |       |      |      |       |       |       |
|--------------|-------|-------|------|------|-------|-------|-------|
| Year:        | 1986  | 1987  | 1990 | 1991 | 1992  | 1993  | 1994  |
| Sample Size: | 15376 | 10609 | 5628 | 7228 | 9601  | 10404 | 13922 |
| Year:        | 1995  | 1996  | 1997 | 1998 | 1999  | 2000  | 2001  |
| Sample Size: | 9216  | 9348  | 9169 | 9583 | 11699 | 12564 | 19750 |

Estimates of total abundance (both in biomass and numbers of fish) obtained from the trawl surveys are shown in Table 2.12, together with the standard errors and upper and lower 95% confidence intervals (CI) for the biomass estimates. Survey results indicate that biomass increased steadily from 1978 through 1983, then remained relatively constant from 1983 through 1989. The highest biomass ever observed by the survey was the 1994 estimate of 1,368,109 t. Following the high observation in 1994, the survey biomass estimate declined steadily through 1998. The survey biomass estimates remained in the 500,000-600,000 t range from 1998 through 2000. This year, however, the survey biomass estimate increased to 830,479 t, a 57% increase over the previous estimate.

In terms of numbers (as opposed to biomass), the record high was observed in 1979, when the population was estimated to include over 1.5 billion fish. The 1994 estimate of population numbers was the second highest on record. After the peak in 1994, numerical declines were observed through 1997, paralleling the biomass time trend. The survey estimate of population numbers hovered around 500 million fish from 1997 through 2000. This year, however, the survey estimate of population numbers increased to 980 million fish, a 104% increase over the previous estimate. This relative increase is the highest on record, more than doubling the previous record of 48% observed in 1993.

### Aleutian Trawl Survey

Biomass estimates for the Aleutian Islands region were derived from U.S.-Japan cooperative trawl surveys conducted during the summers of 1980, 1983, and 1986, and by U.S. trawl surveys of the same area in 1991, 1994, 1997, and 2000. These surveys covered both the Aleutian management area (170 degrees east to 170

degrees west) and a portion of the Bering Sea management area (“Southern Bering Sea”) not covered by the EBS shelf surveys. In 2000, the results from the 1991, 1994, and 1997 surveys were re-calibrated, giving new estimates of biomass for those years. The current time series of biomass estimates from both portions of the Aleutian survey area are shown together with their sum below (all figures are in t):

| Year | Aleutian Management Area | Southern Bering Sea | Aleutian Survey Area |
|------|--------------------------|---------------------|----------------------|
| 1980 | 52,070                   | 74,373              | 126,443              |
| 1983 | 113,148                  | 45,624              | 158,772              |
| 1986 | 172,625                  | 42,298              | 214,923              |
| 1991 | 180,904                  | 8,286               | 189,190              |
| 1994 | 153,026                  | 31,084              | 184,109              |
| 1997 | 72,674                   | 10,742              | 83,416               |
| 2000 | 126,918                  | 9,157               | 136,075              |

As in previous assessments of Pacific cod in the BSAI, a weighted average formed from EBS and Aleutian survey biomass estimates is used in the present assessment to provide a conversion factor which can be used to translate model projections of EBS catch and biomass into BSAI equivalents. Because the assessment model is configured to represent the portion of the Pacific cod population inhabiting the EBS survey area (as opposed to the more extensive EBS *management* area), it seems appropriate to use the biomass estimates from the entire Aleutian survey area (as opposed to the less extensive Aleutian *management* area) to inflate model projections of EBS catch and biomass. Weighted averages of the biomass estimates from the entire Aleutian survey area and their EBS survey area counterparts indicate that, on average, the ratio of Pacific cod biomass in the combined BS and AI management areas to that in the EBS survey area is about 1.17. Because the 83-112 net (with no roller gear) used in the EBS survey generally tends the bottom better than the polyethylene Noreastern net (with roller gear) used in the AI survey, this ratio should tend to err on the conservative side.

### Survey Removals

The amount of Pacific cod removed from the population as a result of NMFS hydroacoustic, longline, and bottom trawl survey operations is summarized for the EBS and AI in Table 2.13. In all years, the magnitude of these removals has been negligible in comparison to the commercial catch (the average ratio of survey removals to commercial removals in the EBS over the period 1978-2001 was approximately 0.001).

### Length at Age, Weight at Length, and Maturity at Length

The set of reliable length at age data for BSAI Pacific cod has been small for the past several years and such data are used only sparingly in this assessment. The otoliths examined from fish sampled during EBS shelf trawl surveys provide the following data regarding the relationship between age and length and the amount of spread around that relationship (lengths, in cm, were measured during summer, and ages are back-dated to January 1):

| Age group:          | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 10  | 11  | 12  |
|---------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Average length:     | 19  | 29  | 37  | 48  | 57  | 65  | 73  | 79  | 82  | 84  | 86  | 89  |
| St. dev. of length: | 3.5 | 5.3 | 5.0 | 4.9 | 4.2 | 3.7 | 4.0 | 5.4 | 7.4 | 5.8 | 7.4 | 7.7 |

Although the supply of reliable length at age data has been severely limited in the past, it now appears likely that such data will become much more available in the future. Studies at the Alaska Fisheries Science Center have resulted in an ageing methodology for Pacific cod that gives reliable age determinations, and production ageing of this species is scheduled to begin soon (Nancy Roberson, pers. commun.).

Weight measurements taken during summer bottom trawl surveys since 1975 yield the following data regarding average weights (in kg) at length, grouped according to size composition bin (as defined under "Catch Size Composition" above):

| Bin Number:  | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 10  | 11  | 12  | 13  | 14  | 15  | 16  | 17  | 18  | 19  | 20  | 21  | 22   | 23   | 24   | 25   |
|--------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|------|------|------|
| Ave. weight: | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.2 | 0.2 | 0.3 | 0.4 | 0.6 | 0.7 | 0.9 | 1.2 | 1.6 | 2.2 | 2.9 | 3.5 | 4.6 | 5.6 | 7.0 | 8.4 | 10.1 | 11.8 | 11.0 | 15.0 |

From 1984 through 1994, assessments of EBS Pacific cod used a maturity schedule based on a logistic function with an inflection at about 61 cm. This schedule was based on a survey sample of fish taken during the 1981-1982 field seasons (see review provided by Thompson and Methot 1993). To update the maturity schedule for Pacific cod, a sampling program was initiated in 1993, using commercial fishery observers. So far, data have been analyzed for 1994 only. These data consist of observers' visual determinations regarding the spawning condition of 2312 females taken in the EBS fishery. Of these 2312 females, 231 were smaller than 42 cm (the lower boundary of length bin 12). None of these sub-42 cm fish were mature. The observed proportions of mature fish in the remaining length bins, together with the numbers of fish sampled in those length bins, are shown below (bins are defined under "Catch Size Composition" above):

| Bin number:   | 12   | 13   | 14   | 15   | 16   | 17   | 18   | 19   | 20   | 21   | 22   | 23   | 24   | 25   |
|---------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| Prop. mature: | 0.03 | 0.05 | 0.14 | 0.19 | 0.28 | 0.53 | 0.69 | 0.82 | 0.89 | 0.94 | 0.94 | 0.91 | 0.89 | 1.00 |
| Sample size:  | 39   | 122  | 226  | 313  | 295  | 300  | 320  | 177  | 103  | 70   | 50   | 35   | 19   | 12   |

## ANALYTIC APPROACH

### Model Structure

This year's model structure is identical to the base model structure used in all assessments of the EBS Pacific cod stock since 1997 (Thompson and Dorn 1997). Beginning with the 1993 SAFE report (Thompson and Methot 1993), a length-structured Synthesis model (Methot 1986, 1989, 1990, 1998) has formed the primary analytical tool used to assess the EBS Pacific cod stock. Synthesis is a program that uses the parameters of a set of equations governing the assumed dynamics of the stock (the "model parameters") as surrogates for the parameters of statistical distributions from which the data are assumed to be drawn (the "distribution parameters"), and varies the model parameters systematically in the direction of increasing likelihood until a maximum is reached. The overall likelihood is the product of the likelihoods for each of the model components. Each likelihood component is associated with a set of data assumed to be drawn from statistical distributions of the same general form (e.g., multinomial, lognormal, etc.). Typically, likelihood components are associated with data sets such as catch size (or age) composition, survey size (or age) composition, and survey biomass.

Symbols used in the stock assessment model are listed in Table 2.14 (note that this list applies to the stock assessment model only, and does not include all symbols used in the "Projections and Harvest Alternatives" section of this assessment or Appendices 2B and 2C). Synthesis uses a total of 16 dimensional constants, special values of indices, and special values of continuous variables, all of which are listed on the first page of Table 2.14. The values of these quantities are not estimated statistically, in the strict sense, but are typically set by assumption or as a matter of structural specification. The values of these constants, indices, and variables are listed in Table 2.15, with a brief rationale given for each value used. In contrast to the quantities whose values are specified in Table 2.15, Synthesis uses a large number of parameters that are estimated statistically (though the estimation itself may not necessarily take place within Synthesis). For ease of reference, capital Roman letters are used to designate such "Synthesis parameters," which are listed on the second page of Table 2.14.

Functional representations of population dynamics are given in Appendix 2A, using the symbols defined in Table 2.14. It should be noted that, while the equations given in Appendix 2A are generally similar to those used in Synthesis, they may differ in detail. Also, only a subset of the equations actually used by Synthesis is shown. Basically, enough equations are shown to illustrate at least one use for each of the symbols shown in Table 2.14.

The assessments conducted during the period 1997-1999 (Thompson and Dorn 1997, Thompson and Dorn 1998, Thompson and Dorn 1999) used approximate Bayesian methods to address uncertainty surrounding the true values of two key model parameters, the natural mortality rate  $M$  and the survey catchability coefficient  $Q$ . Due to limitations of the Synthesis software, a type of meta-analysis was used to implement the Bayesian portion of those assessments. This meta-analysis involved fitting a pair of bivariate distributions to the log-likelihood maxima and projected  $F_{40\%}$  catches returned from a very large number of individual model runs, each of which held  $M$  and  $Q$  constant at a unique pair of values. The pairs of  $M$  and  $Q$  values corresponded to points placed at regularly spaced intervals within a grid spanning the 95% confidence ellipse of the fitted bivariate log-likelihood surface. The purpose of the Bayesian meta-analysis was to recommend an ABC that accounted for parameter uncertainty in an appropriately risk-averse manner. This was accomplished by setting the recommended ABC equal to the geometric mean of the catch distribution corresponding to the product of the catch profile and the posterior distribution. However, the Bayesian meta-analysis was always extremely labor intensive. In the course of conducting the 2000 stock assessment (Thompson and Dorn 2000), it therefore seemed prudent to seek an efficient shortcut. Looking

back at the results of the 1997-1999 stock assessments, it appeared that the ratio between the recommended  $F_{ABC}$  emerging from the Bayesian meta-analysis and the  $F_{40\%}$  estimate emerging from the base model was converging over time. The average value of this ratio over the 1997-1999 period was 0.86, with a 1999 value of 0.87. Interestingly, identical three-year average and 1999 values were obtained in the 1997-1999 assessments of the GOA Pacific cod stock (Thompson et al. 1997, Thompson et al. 1998, Thompson et al. 1999). Because the 1999 value represented the most recent estimate and was approximately equal to the 1997-1999 average, the 2000 stock assessment multiplied this value (0.87) by the maximum permissible  $F_{ABC}$  to obtain the recommended  $F_{ABC}$ . The resulting ABC recommendation was accepted by the SSC and the Council. The same procedure is used in the present assessment, thereby eliminating the need to re-perform the Bayesian meta-analysis. For future assessments, Appendices 2B and 2C describe a modeling framework which should permit a more thorough yet less labor-intensive Bayesian solution.

### Parameters Estimated Independently

Table 2.16 divides the set of Synthesis parameters into two parts, the first of which lists those parameters that were estimated independently (i.e., outside of Synthesis), and the second of which lists those parameters that were estimated conditionally (i.e., inside of Synthesis). This section describes the estimation of parameters in the first part of Table 2.16.

#### Natural Mortality

The natural mortality rate was estimated independently of other parameters at a value of 0.37. This value was used in the present assessment for the following reasons: 1) it was derived as the maximum likelihood estimate of  $M$  in the 1993 BSAI Pacific cod assessment, 2) it has been used to represent  $M$  in all BSAI Pacific cod assessments since 1993 and in all GOA Pacific cod assessments except one since 1994, 3) it was explicitly accepted by the SSC for use as an estimate of  $M$  in the GOA Pacific cod assessment (SSC minutes, December, 1994), and 4) it lies well within the range of previously published estimates of  $M$  shown below:

| Area               | Author                | Year | Value     |
|--------------------|-----------------------|------|-----------|
| Eastern Bering Sea | Low                   | 1974 | 0.30-0.45 |
|                    | Wespestad et al.      | 1982 | 0.70      |
|                    | Bakkala and Wespestad | 1985 | 0.45      |
|                    | Thompson and Shimada  | 1990 | 0.29      |
|                    | Thompson and Methot   | 1993 | 0.37      |
| Gulf of Alaska     | Thompson and Zenger   | 1993 | 0.27      |
|                    | Thompson and Zenger   | 1995 | 0.50      |
| British Columbia   | Ketchen               | 1964 | 0.83-0.99 |
|                    | Fournier              | 1983 | 0.65      |

### Trawl Survey Catchability

The trawl survey catchability coefficient was estimated independently of other parameters at a value of 1.0. This value was used in the present assessment mostly because it has been used in all previous assessments. Also, preliminary results of recent experimental work conducted in the EBS by the Alaska Fisheries Science Center's Resource Assessment and Conservation Engineering Division tend to confirm that this is a reasonable value (David Somerton, pers. commun.).

### Weight at Length

Parameters (Table 2.14) governing the relationship between weight and length (Appendix 2A) were estimated by log-log regression from the available data (see "Data" above), giving the following values (weights are in kg, lengths in cm):  $W_1 = 4.36 \times 10^{-6}$ ,  $W_2 = 3.242$ .

### Length at First Age of Survey Observation

Assuming that the first age at which Pacific cod are seen in the trawl survey ( $\alpha_1$ , Table 2.14) is approximately 1.5 years, the length at this age ( $L_1$ , Table 2.14) as estimated to be 16.2 cm by averaging the lengths corresponding to the first mode greater than or equal to 14 cm (bin 2) from each of the five most recent survey size compositions.

### Variability in Length at Age

Parameters (Table 2.14) governing the amount of variability surrounding the length-at-age relationship (Appendix 2A) were estimated directly from the observed standard deviations in the available length-at-age data (see "Data" above), giving the following values (in cm):  $X_1 = 3.5$ ,  $X_2 = 7.7$ . Estimation of these two parameters constituted the only use of age data in the present assessment.

### Maturity at Length

Maximum likelihood estimates of the parameters (Table 2.14) governing the female maturity-at-length schedule (Appendix 2A) were obtained using the method described by Prentice (1976), giving the following values:  $P_1 = 0.142$ ,  $P_2 = 67.1$  cm. The variance-covariance matrix of the parameter estimates gave a standard deviation of 0.006 for the estimate of  $P_1$ , a standard deviation of 0.39 cm for the estimate of  $P_2$ , and a correlation of -0.154 between the estimates of the two parameters.

### Parameters Estimated Conditionally

Those Synthesis parameters that are estimated internally are listed in the second part of Table 2.16. The estimates of these parameters are conditional on each other, as well as on those listed in the first part of the table and discussed in the preceding section (i.e., those Synthesis parameters that are estimated independently).

### Likelihood Components

As noted in the "Model Structure" section, Synthesis is a likelihood-based framework for parameter estimation which allows several data components to be considered simultaneously. In this assessment, four fishery size composition likelihood components were included: the January-May ("early") trawl fishery, the June-December ("late") trawl fishery, the longline fishery, and the pot fishery. In addition to the fishery size

composition components, likelihood components for the size composition and biomass trend from the bottom trawl survey were included in the model. To account for possible differences in selectivity between the mostly foreign (also joint venture) and mostly domestic fisheries, the fishery size composition time series were split into pre-1989 and post-1988 eras. Also, to account for the effects of a change in the trawl survey gear, the survey size composition and biomass time series were split into pre-1982 and post-1981 eras.

The Synthesis program allows the modeler to specify “emphasis” factors that determine which components receive the greatest attention during the parameter estimation process. As in previous assessments, each component was given an emphasis of 1.0 in the present assessment.

#### Use of Size Composition Data in Parameter Estimation

Size composition data are assumed to be drawn from a multinomial distribution specific to a particular year, gear/fishery, and time period within the year. In the parameter estimation process, Synthesis weights a given size composition observation (i.e., the size frequency distribution observed in a given year, gear/fishery, and period) according to the emphasis associated with the respective likelihood component and the sample size specified for the multinomial distribution from which the data are assumed to be drawn. In developing the model upon which Synthesis was originally based, Fournier and Archibald (1982) suggested truncating the multinomial sample size at a value of 400 in order to compensate for contingencies which cause the sampling process to depart from the process that gives rise to the multinomial distribution. As in previous assessments, the present assessment uses a multinomial sample size equal to the square root of the true sample size, rather than the true sample size itself. Given the true sample sizes observed in the present assessment, this procedure tends to give values somewhat below 400 while still providing the Synthesis program with usable information regarding the appropriate effort to devote to fitting individual samples. Multinomial sample sizes derived by this procedure for the commercial fishery size compositions are shown in Table 2.17. In the case of survey size composition data, the square root assumption was also used, except that it was necessary to assume a true sample size for the years 1979-1985 and 1988-1989, years for which such measures are unavailable (see “Trawl Survey Data” above). For those years, a true sample size of 10,000 fish was assumed (giving a multinomial sample size of 100), which approximates the average of the 10 known true sample sizes from the years 1986-1997. For the years 1986-1987 and 1990-2001, the square roots (SR) of the true survey sample sizes are shown below:

|                  |      |      |      |      |      |      |      |
|------------------|------|------|------|------|------|------|------|
| Year:            | 1986 | 1987 | 1990 | 1991 | 1992 | 1993 | 1994 |
| SR(sample size): | 124  | 103  | 75   | 85   | 98   | 102  | 118  |
| Year:            | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 |
| SR(sample size): | 96   | 97   | 96   | 98   | 108  | 112  | 141  |

#### Use of Survey Biomass Data in Parameter Estimation

Each year’s survey biomass datum is assumed to be drawn from a lognormal distribution specific to that year. The model’s estimate of survey biomass in a given year serves as the geometric mean for that year’s lognormal distribution, and the ratio of the survey biomass datum’s standard error to the survey biomass datum itself serves as the distribution’s coefficient of variation.

### MODEL EVALUATION

Only a single model is considered in the present assessment.

## Evaluation Criteria

Two criteria will be used to evaluate the model developed in the present assessment: 1) the effective sample sizes of the size composition data and 2) the root mean squared error (RMSE) of the fit to the survey biomass data.

### Effective Sample Size

Once maximum likelihood estimates of the model parameters have been obtained, Synthesis computes an “effective” sample size for the size composition data specific to a particular year, gear/fishery, and time period within the year. Roughly, the effective sample size can be interpreted as the multinomial sample size that would typically be required in order to produce the given fit. More precisely, it is the sample size that sets the sum of the marginal variances of the proportions implied by the multinomial distribution equal to the sum of the squared differences between the sample proportions and the estimated proportions (McAllister and Ianelli 1997). As a function of a multinomial random variable, the effective sample size has its own distribution. The harmonic mean of the distribution is equal to the true sample size in the multinomial distribution. Thus, if the effective sample size is less than the true sample size in the multinomial distribution, it is reasonable to conclude that the fit is not as good as expected. The following table shows the average of the input sample sizes and the average effective sample sizes for each of the size composition components (in each column, the average is computed with respect to all years and periods present in the respective time series):

| Likelihood Component              | Ave. Effective<br>Sample Size | Ave. Input<br>Sample Size | Ratio |
|-----------------------------------|-------------------------------|---------------------------|-------|
| Early-season trawl fishery size   | 193                           | 197                       | 0.98  |
| Late-season trawl fishery size    | 74                            | 45                        | 1.64  |
| Longline fishery size composition | 269                           | 187                       | 1.44  |
| Pot fishery size composition      | 246                           | 119                       | 2.07  |
| Pre-1982 survey size composition  | 90                            | 100                       | 0.90  |
| Post-1981 survey size composition | 145                           | 103                       | 1.42  |

Note: True sample sizes for the survey are available only for the years 1986-1987 and 1990-2001. For all other years, a value of 10,000 (square root = 100) was assumed.

The model produces average effective samples considerably larger than the average input values for most likelihood components. The ratios shown in the above table range from 1.42 to 2.07 for the post-1981 survey, the longline fishery, the late-season trawl fishery, and the pot fishery. The early-season trawl fishery and the pre-1982 survey are the only components that produce ratios less than unity. However, the ratio for the pre-1982 survey is not particularly meaningful because the true sample sizes for those years are unknown.

### Fit to Survey Biomass Data

The log-scale RMSE from the model’s fit to the survey biomass time series is 0.192. This is a little more than twice the average log-scale standard error in the data (0.091).

## Parameter Estimates Associated with the Final Model

The model estimated length-at-age parameter values of  $K = 0.215$  and  $L_2 = 93.3$ . Estimates of fishing mortality rates  $F_{g,y,i}$ , recruitments  $R_y$ , and initial numbers at age  $N_a$ , and selectivity parameters  $S_{1-7,g,e(y|g)}$  are shown in Tables 2.18, 2.19, and 2.20, respectively. In addition, the parameter estimates listed in the section entitled “Parameters Estimated Independently” also pertain.

## Schedules Defined by Final Parameter Estimates

Lengths at age defined by the final parameter estimates are shown below (lengths are in cm and are evaluated at the mid-point of each age group):

| Age group:      | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 | 11 | 12 |
|-----------------|----|----|----|----|----|----|----|----|----|----|----|----|
| Average length: | 17 | 34 | 47 | 58 | 66 | 73 | 79 | 83 | 87 | 90 | 92 | 96 |

The distribution of lengths at age (measured in mid-year) defined by the final parameter estimates is shown in Table 2.21.

Weights at length and maturity proportions at length defined by the final parameters are shown in Table 2.22, and selectivities at length defined by the final parameter estimates are shown in Table 2.23.

## RESULTS

### Definitions

The biomass estimates presented here will be defined in three ways: 1) age 3+ biomass, consisting of the biomass of all fish aged three years or greater in January of a given year (vector  $b$  in Appendix 2A); 2) spawning biomass, consisting of the biomass of all spawning females in March of a given year (vector  $c$  in Appendix 2A); and 3) survey biomass, consisting of the biomass of all fish that the Model estimates should have been observed by the survey in July of a given year (vector  $d$  in Appendix 2A). The recruitment estimates presented here will be defined in two ways: 1) as numbers of age 3 fish in January of a given year and 2) as the recruitment parameter  $R_y$ , which represents numbers at age 1 in January of year  $y$ . The fishing mortality rates presented here will be defined as full-selection, instantaneous fishing mortality rates expressed on a per annum scale.

### Biomass

The model’s estimate of the recent history of the stock (EBS portion only) is shown in Table 2.24, together with estimates provided in last year’s final SAFE report (Thompson and Dorn 2000). The biomass trends estimated in the present assessment are also shown in Figure 2.7. The model’s estimated time series of “survey” biomass parallels the biomass trend from the actual survey fairly closely, particularly during the 1980s. The model’s estimate of survey biomass is within two standard deviations of the survey point estimate in 18 out of the 23 years in the time series. Exceptions occur in the case of the 1992 estimate, where the model is more than two standard deviations high, and in the cases of the 1979, 1994, 1995, and 2001 estimates, where the model is more than two standard deviations low.

The model’s estimated age 3+ biomass shows a continual decline since 1987. The model’s estimated

spawning biomass shows a continual decline from 1987 through 2000, with a slight (0.1%) increase in 2001. The model's estimate of 2001 age 3+ biomass is the lowest in the time series since 1980, and the model's estimates of 2000-2001 spawning biomass are the lowest in the time series since 1981.

## Recruitment

### Numbers at Age 3

Traditionally, recruitment strengths for Pacific cod have been assessed at age 3, because this is the approximate age of first significant recruitment to the fishery and because model estimates of relative year class strength tend to stabilize by this age. The model's estimated time series of age 3 recruitments is shown in Table 2.25, together with the estimates provided in last year's final SAFE report (Thompson and Dorn 2000). The model's recruitment estimates are also plotted in Figure 2.8. The current time series has a mean value of 240 million fish, a coefficient of variation of 61%, and an autocorrelation coefficient of -0.059.

One possible means of assigning a qualitative ranking to each year class within this time series is as follows: an "above average" year class can be defined as one in which numbers at age 3 are at least 120% of the mean, an "average" year class can be defined as one in which numbers at age 3 are less than 120% of the mean but at least 80% of the mean, and a "below average" year class can be defined as one in which numbers at age 3 are less than 80% of the mean. These criteria give the following classification of year class strengths:

|                |      |      |      |      |      |      |      |      |      |      |      |      |      |
|----------------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| Above average: | 1977 | 1978 | 1979 | 1982 | 1984 | 1989 | 1992 |      |      |      |      |      |      |
| Average:       | 1980 | 1985 | 1990 | 1996 |      |      |      |      |      |      |      |      |      |
| Below average: | 1975 | 1976 | 1981 | 1983 | 1986 | 1987 | 1988 | 1991 | 1993 | 1994 | 1995 | 1997 | 1998 |

Except for the addition of the 1998 year class to the "below average" category, these results are identical to those presented in last year's SAFE report (Thompson and Dorn 2000).

### Numbers at Age 1

The model's estimated time series of age 1 recruitments is shown in Table 2.19. This time series has a mean value of 537 million fish, a coefficient of variation of 57%, and an autocorrelation coefficient of -0.016. The qualitative rankings of year class strengths at age 1 naturally parallel the rankings at age 3, except that estimates for the 1975 and 1976 year classes do not exist at age 1 and the 1999 and 2000 year classes are added to the time series (in addition, the ranking of the 1989 year class changes from "average" at age 1 to "above average" at age 3; it is near the cutoff point in both cases). The 1999 year class appears to be solidly in the "average" category, while the 2000 year class appears to be well above average. The model's estimate of age 1 recruitment from the 2000 year class is the fourth highest in the time series, although it should be noted that this estimate is based almost entirely on the 2001 survey size composition data.

The present assessment model is not configured to estimate a stock-recruitment relationship. Estimation of stock-recruitment relationships is a notoriously difficult exercise in the field of stock assessment, because both the stock data and the recruitment data are measured with error and because the errors in the stock-recruitment data are autocorrelated (Walters and Ludwig 1981). Also, if the stock and recruitment data are generated by a model which assumes that no stock-recruitment relationship exists, these data will be biased. Nevertheless, the stock-recruitment relationship is potentially such an important component of stock dynamics that it seems prudent to provide some kind of investigation, albeit provisional, as to its possible shape. In addition, the SSC has requested that the assessment include a stock-recruitment relationship (SSC

minutes, December, 2000). To this end, the following analysis was conducted (use of symbols in this description does not necessarily follow Table 2.14, which pertains to the Synthesis assessment model only):

- 1) Age 1 recruitment  $R$  in year  $y+1$  was assumed to be related to spawning biomass  $S$  in year  $y$  by the Ricker (1954) stock-recruitment relationship subject to lognormal error:

$$R_{y+1} = S_y \exp(-\alpha - \beta S_y + \varepsilon_y),$$

where  $\alpha$  and  $\beta$  are parameters and the  $\varepsilon_y$  are drawn from a normal distribution with mean 0 and variance  $\sigma^2$ .

- 2) The estimates of spawning biomass generated by Synthesis were treated as known constants (i.e., it was assumed that they are measured without error).
- 3) Parameters were estimated by the method of maximum likelihood.
- 4) The covariance of the parameter estimates was assumed to equal the inverse of the Hessian matrix.

The point estimates of the parameters were  $\alpha = -1.814$ ,  $\beta = 0.003537$ , and  $\sigma = 0.582$ . The 95% confidence interval of the stock-recruitment parameters is shown in the upper panel of Figure 2.9. One of the attractive features of the method described above is that it implies that the stock-recruitment relationship  $r(S) = S \exp(-\alpha - \beta S)$  is itself a lognormal random variable with parameters that are functions of stock size. The coefficient of variation for the relationship is minimized at the mean of the stock data. The lower panel of Figure 2.9 shows the data (solid squares), the stock-recruitment relationship defined by the point estimates of the parameters (thick curve), and the 95% confidence interval around the stock-recruitment relationship (thin curves). This analysis is useful mostly because it indicates a considerable level of uncertainty regarding the shape of the stock-recruitment relationship. Moreover, this description of uncertainty should be regarded as an underestimate because of the problems noted in the paragraph above. The estimates given here are not recommended for use in estimating maximum sustainable yield.

The SSC has suggested that occurrence of strong year classes may depend “on the presence of a broad age distribution in the spawning stock” (SSC minutes, December, 2000). A natural way to define “breadth” is the number of age groups present in the spawning stock. However, this definition is difficult to use in practice for two reasons. First, the number of explicit ages in the present model is fixed, with an indeterminate number of ages represented implicitly in the “age-plus” group. Second, even if all potential age groups were represented in the model explicitly, the difficulty of determining the presence or absence of a particular age group in the population varies inversely with the number of individuals in that age group (in which case variation in the *estimated* breadth may be due more to variation in sampling intensity than variation in the *actual* breadth). Alternatively, “breadth” could be measured in terms of the diversity or evenness of the age structure. Two such measures are the Shannon-Wiener information index

$$\sum_{a=a_{\min}}^{a_{\max}} \theta_a \ln(\theta_a)$$

and the Simpson diversity index

$$1 - \sum_{a=a_{\min}}^{a_{\max}} \theta_a^2, \text{ where } \theta_a \text{ is the proportion of the spawning population contained in age group } a.$$

Table 2.27 shows the age structures of the total population (ages 1 and above) and the spawning population over time. Table 2.28 compares the values of the Shannon-Wiener information index and the Simpson diversity index with lagged age 1 recruitment. The correlation between both indices and subsequent recruitment is negative (-0.324 and -0.294, respectively). Similar to the method described above for ranking Pacific cod recruitment at age 3, a year class can be defined here as “strong” if its age 1 recruitment exceeds 120% of the time series average, “average” if its age 1 recruitment is between 80% and 120% of the time series average, and “weak” if its age 1 recruitment is less than 80% of the time series average. The ranges of index values corresponding to strong, average, and weak year classes are summarized in the table below:

| Year class rank | Shannon-Wiener index |             | Simpson index |             |
|-----------------|----------------------|-------------|---------------|-------------|
|                 | <u>Low</u>           | <u>High</u> | <u>Low</u>    | <u>High</u> |
| Strong          | 1.38                 | 2.21        | 0.65          | 0.88        |
| Average         | 1.60                 | 2.16        | 0.77          | 0.87        |
| Weak            | 1.48                 | 2.23        | 0.69          | 0.88        |

Note that the minimum index values corresponding to strong year classes are lower than the respective values corresponding to either average or weak year classes. The available information therefore does not corroborate the hypothesis that strong year classes depend on the presence of a broad age distribution in the spawning stock, although this may simply reflect sufficient breadth in the age structure of the spawning stock throughout the entire time series.

### Exploitation

The model’s estimated time series of the ratio between EBS catch and age 3+ biomass is shown in Table 2.26, together with the estimates provided in last year’s final SAFE report (Thompson and Dorn 2000). The average value of this ratio over the entire time series is about 0.08. The estimated values exceed the average for every year after 1990 except 1993 and 2001 (the entry for 2001 is based on a partial estimate of catch), whereas none of the estimated values exceed the average in any year prior to 1990 except 1978.

## PROJECTIONS AND HARVEST ALTERNATIVES

### Amendment 56 Reference Points

Amendment 56 to the BSAI Groundfish Fishery Management Plan (FMP) defines the “overfishing level” (OFL), the fishing mortality rate used to set OFL ( $F_{OFL}$ ), the maximum permissible ABC, and the fishing mortality rate used to set ABC ( $F_{ABC}$ ) may be less than this maximum permissible level, but not greater. Because reliable estimates of reference points related to maximum sustainable yield (MSY) are currently not available but reliable estimates of reference points related to spawning per recruit are available, Pacific cod in the BSAI are managed under Tier 3 of Amendment 56. Tier 3 uses the following reference points:  $B_{40\%}$ , equal to 40% of the equilibrium spawning biomass that would be obtained in the absence of fishing;  $F_{35\%}$ , equal to the fishing mortality rate that reduces the equilibrium level of spawning per recruit to 35% of the level that would be obtained in the absence of fishing; and  $F_{40\%}$ , equal to the fishing mortality rate that reduces the equilibrium level of spawning per recruit to 40% of the level that would be obtained in the absence of fishing. The following formulae apply under Tier 3:

$$\begin{aligned}
3a) \text{ Stock status: } B/B_{40\%} &> 1 \\
F_{OFL} &= F_{35\%} \\
F_{ABC} &\leq F_{40\%} \\
3b) \text{ Stock status: } 1/20 < B/B_{40\%} &\leq 1 \\
F_{OFL} &= F_{35\%} \times (B/B_{40\%} - 1/20) \times 20/19 \\
F_{ABC} &\leq F_{40\%} \times (B/B_{40\%} - 1/20) \times 20/19 \\
3c) \text{ Stock status: } B/B_{40\%} &\leq 1/20 \\
F_{OFL} &= 0 \\
F_{ABC} &= 0
\end{aligned}$$

Estimation of the  $B_{40\%}$  reference point used in the above formulae requires an assumption regarding the equilibrium level of recruitment. In this assessment, it is assumed that the equilibrium level of recruitment is equal to the post-1976 average (i.e., the arithmetic mean of all estimated recruitments from year classes spawned in 1977 or later). Other useful biomass reference points which can be calculated using this assumption are  $B_{100\%}$  and  $B_{35\%}$ , defined analogously to  $B_{40\%}$ . These reference points are estimated as follows:

| Reference point: | $B_{35\%}$ | $B_{40\%}$ | $B_{100\%}$ |
|------------------|------------|------------|-------------|
| EBS:             | 322,000 t  | 368,000 t  | 923,000 t   |
| BSAI:            | 377,000 t  | 431,000 t  | 1,080,000 t |

For a stock exploited by multiple gear types, estimation of  $F_{35\%}$  and  $F_{40\%}$  requires an assumption regarding the apportionment of fishing mortality among those gear types. Current regulations specify that catches of Pacific cod will be allocated according to gear type as follows: the trawl fishery will be allocated 47%, the fixed gear (longline and pot) fishery will be allocated 51%, and the jig fishery will be allocated 2%; of the fixed gear allocation, the longline fishery will be allocated 80.3% (not counting catcher vessels less than 60 ft LOA), the pot fishery will be allocated 18.3% (not counting catcher vessels less than 60 ft. LOA), and fixed-gear catcher vessels less than 60 ft. LOA will be allocated 1.4%. This allocation formula was then integrated into calculation of reference points in this assessment as follows: First, to simplify the analysis, it was assumed that the 1.4% of the fixed-gear allocation that is reserved for catcher vessels less than 60 ft. LOA would be taken in the longline fishery. Second, since available data are insufficient to estimate selectivities for the jig fishery, the jig fishery was merged into the other commercial fisheries. Third, total fishing mortality was apportioned between gear types (early trawl, late trawl, longline, and pot) at a ratio of 371:51:469:109. These proportions result in a 2002 catch composition that matches both the 47:51 trawl:fixed allocation, the 817:183 longline:pot allocation and the recent (1998-2000) average distribution of catches between the early and late trawl fisheries. It should be noted that this apportionment scheme is generally consistent with the “preferred alternative” described in the Steller Sea Lion Protection Measures Draft Supplemental Environmental Impact Statement, although the latter is considerably more detailed. This apportionment results in the following estimates of  $F_{35\%}$  and  $F_{40\%}$ :

|            |            |
|------------|------------|
| $F_{35\%}$ | $F_{40\%}$ |
| 0.36       | 0.30       |

#### Specification of OFL and Maximum Permissible ABC

BSAI spawning biomass for 2002 is estimated at a value of 425,000 t (EBS value = 363,000 t). This is about 1% below the BSAI  $B_{40\%}$  value of 431,000 t (EBS value = 368,000 t), thereby placing Pacific cod in sub-tier

“b” of Tier 3. Given this, the model estimates OFL, maximum permissible ABC, and the associated fishing mortality rates for 2002 as follows:

|                         | Overfishing Level | Maximum Permissible ABC |
|-------------------------|-------------------|-------------------------|
| EBS catch:              | 251,000 t         | 216,000 t               |
| BSAI catch:             | 294,000 t         | 253,000 t               |
| Fishing mortality rate: | 0.35              | 0.30                    |

For comparison, the age 3+ biomass estimates for 2002 are 1,540,000 t and 1,320,000 t for the BSAI and EBS, respectively.

#### ABC Recommendation

It is important to remember that the maximum permissible ABC computed under the stock assessment model is only a point estimate, around which there is significant uncertainty. For the past several years, the BSAI and GOA Pacific cod assessments have advocated a harvest strategy that formally addresses some of this uncertainty, namely the uncertainty surrounding parameters  $M$  and  $Q$  (see “Model Structure” above). For the assessment conducted in 2000, the strategy was simplified by assuming that the ratio between the recommended  $F_{ABC}$  and  $F_{40\%}$  estimate given in the 1999 assessment (0.87) was an appropriate factor by which to multiply the 2001 maximum permissible  $F_{ABC}$  to obtain a recommended 2001  $F_{ABC}$ . The same strategy is recommended for setting the 2002 ABC. This strategy results in a recommended 2002 BSAI ABC of 223,000 t (EBS value = 191,000 t), corresponding to a fishing mortality rate of 0.26.

#### Standard Harvest and Recruitment Scenarios and Projection Methodology

A standard set of projections is required for each stock managed under Tiers 1, 2, or 3 of Amendment 56. This set of projections encompasses seven harvest scenarios designed to satisfy the requirements of Amendment 56, the National Environmental Policy Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

For each scenario, the projections begin with the vector of 2001 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2002 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2001. In each subsequent year, the fishing mortality rate is prescribed on the basis of the spawning biomass in that year and the respective harvest scenario. In each year, recruitment is drawn from an inverse Gaussian distribution whose parameters consist of maximum likelihood estimates determined from recruitments estimated in the assessment. Spawning biomass is computed in each year based on the time of peak spawning and the maturity and weight schedules described in the assessment. Total catch is assumed to equal the catch associated with the respective harvest scenario in all years. This projection scheme is run 1000 times to obtain distributions of possible future stock sizes, fishing mortality rates, and catches.

Five of the seven standard scenarios will be used in an Environmental Assessment prepared in conjunction with the final SAFE. These five scenarios, which are designed to provide a range of harvest alternatives that are likely to bracket the final TAC for 2002, are as follow (“ $\max F_{ABC}$ ” refers to the maximum permissible value of  $F_{ABC}$  under Amendment 56):

*Scenario 1:* In all future years,  $F$  is set equal to  $\max F_{ABC}$ . (Rationale: Historically, TAC has been constrained by ABC, so this scenario provides a likely upper limit on future TACs.)

*Scenario 2:* In all future years,  $F$  is set equal to a constant fraction of  $\max F_{ABC}$ , where this fraction is equal to the ratio of the  $F_{ABC}$  value for 2002 recommended in the assessment to the  $\max F_{ABC}$  for 2000. (Rationale: When  $F_{ABC}$  is set at a value below  $\max F_{ABC}$ , it is often set at the value recommended in the stock assessment.)

*Scenario 3:* In all future years,  $F$  is set equal to 50% of  $\max F_{ABC}$ . (Rationale: This scenario provides a likely lower bound on  $F_{ABC}$  that still allows future harvest rates to be adjusted downward when stocks fall below reference levels.)

*Scenario 4:* In all future years,  $F$  is set equal to the 1996-2000 average  $F$ , which was 0.19. (Rationale: For some stocks, TAC can be well below ABC, and recent average  $F$  may provide a better indicator of  $F_{TAC}$  than  $F_{ABC}$ .)

*Scenario 5:* In all future years,  $F$  is set equal to zero. (Rationale: In extreme cases, TAC may be set at a level close to zero.)

Two other scenarios are needed to satisfy the MSFCMA's requirement to determine whether a stock is currently in an overfished condition or is approaching an overfished condition. These two scenarios are as follow (for Tier 3 stocks, the MSY level is defined as  $B_{35\%}$ ):

*Scenario 6:* In all future years,  $F$  is set equal to  $F_{OFL}$ . (Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be above  $\frac{1}{2}$  of its MSY level in 2002 and above its MSY level in 2012 under this scenario, then the stock is not overfished.)

*Scenario 7:* In 2002 and 2003,  $F$  is set equal to  $\max F_{ABC}$ , and in all subsequent years,  $F$  is set equal to  $F_{OFL}$ . (Rationale: This scenario determines whether a stock is approaching an overfished condition. If the stock is expected to be above its MSY level in 2014 under this scenario, then the stock is not approaching an overfished condition.)

### Projections and Status Determination

Table 2.29 defines symbols used to describe projections of spawning biomass, fishing mortality rate, and catch corresponding to the seven standard harvest scenarios. These projections are shown in Tables 2.30-36. Overall, these projections indicate that spawning biomass will probably decline through 2003 except under the most conservative exploitation strategies (Scenarios 3 and 5).

Harvest scenarios #6 and #7 are intended to permit determination of the status of a stock with respect to its minimum stock size threshold (MSST). Any stock that is below its MSST is defined to be *overfished*. Any stock that is expected to fall below its MSST in the next two years is defined to be *approaching* an overfished condition. Harvest scenarios #6 and #7 are used in these determinations as follows:

*Is the stock overfished?* This depends on the stock's estimated spawning biomass in 2002:

- If spawning biomass for 2002 is estimated to be below  $\frac{1}{2} B_{35\%}$ , the stock is below its MSST.
- If spawning biomass for 2002 is estimated to be above  $B_{35\%}$ , the stock is above its MSST.
- If spawning biomass for 2002 is estimated to be above  $\frac{1}{2} B_{35\%}$  but below  $B_{35\%}$ , the stock's status relative to MSST is determined by referring to harvest scenario #6 (Table 2.35). If the mean

spawning biomass for 2012 is below  $B_{35\%}$ , the stock is below its MSST. Otherwise, the stock is above its MSST.

*Is the stock approaching an overfished condition?* This is determined by referring to harvest scenario #7 (Table 2.36):

- a) If the mean spawning biomass for 2004 is below  $\frac{1}{2} B_{35\%}$ , the stock is approaching an overfished condition.
- b) If the mean spawning biomass for 2004 is above  $B_{35\%}$ , the stock is not approaching an overfished condition.
- c) If the mean spawning biomass for 2004 is above  $\frac{1}{2} B_{35\%}$  but below  $B_{35\%}$ , the determination depends on the mean spawning biomass for 2014. If the mean spawning biomass for 2014 is below  $B_{35\%}$ , the stock is approaching an overfished condition. Otherwise, the stock is not approaching an overfished condition.

In the case of BSAI Pacific cod, spawning biomass for 2002 is estimated to be above  $B_{35\%}$ . Therefore, the stock is above its MSST and is not overfished. Mean spawning biomass for 2004 in Table 2.36 is above  $B_{35\%}$ . Therefore, the stock is not approaching an overfished condition.

## OTHER CONSIDERATIONS

The prey and predators of Pacific cod have been described or reviewed by Albers and Anderson (1985), Livingston (1989, 1991), and Westrheim (1996). In terms of percent occurrence, the most important items in the diet of Pacific cod in the BSAI and GOA are polychaetes, amphipods, and crangonid shrimp. In terms of numbers of individual organisms consumed, the most important dietary items are euphausiids, miscellaneous fishes, and amphipods. In terms of weight of organisms consumed, the most important dietary items are walleye pollock, fishery offal, and yellowfin sole. Small Pacific cod feed mostly on invertebrates, while large Pacific cod are mainly piscivorous. Predators of Pacific cod include halibut, salmon shark, northern fur seals, Steller sea lions, harbor porpoises, various whale species, and tufted puffin.

The above qualitative description of Pacific cod's trophic relationships notwithstanding, to date it has not been possible to incorporate ecosystem interactions into the model used to assess the Pacific cod stock. No recommendations regarding adjustment of the Pacific cod ABC on the basis of ecosystem considerations are made at this time.

## SUMMARY

The major results of the Pacific cod stock assessment are summarized in Table 2.37.

## REFERENCES

- Albers, W. D., and P. J. Anderson. 1985. Diet of Pacific cod, *Gadus macrocephalus*, and predation on the northern pink shrimp, *Pandalus borealis*, in Pavlof Bay, Alaska. Fish. Bull., U.S. 83:601-610.
- Bakkala, R. G., and V. G. Wespestad. 1985. Pacific cod. In R. G. Bakkala and L. L. Low (editors), Condition of groundfish resources of the eastern Bering Sea and Aleutian Islands region in 1984, p. 37-49. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-83.
- Fournier, D. A. 1983. An analysis of the Hecate Strait Pacific cod fishery using an age-structured model incorporating density-dependent effects. Can. J. Fish. Aquat. Sci. 40:1233-1243.
- Fournier, D., and C. P. Archibald. 1982. A general theory for analyzing catch at age data. Can. J. Fish. Aquat. Sci. 38:1195-1207.
- Grant, W. S., C. I. Zhang, and T. Kobayashi. 1987. Lack of genetic stock discretion in Pacific cod (*Gadus macrocephalus*). Can. J. Fish. Aquat. Sci. 44:490-498.
- Ketchen, K.S. 1964. Preliminary results of studies on a growth and mortality of Pacific cod (*Gadus macrocephalus*) in Hecate Strait, British Columbia. J. Fish. Res. Bd. Canada 21:1051-1067.
- Livingston, P. A. 1989. Interannual trends in Pacific cod, *Gadus macrocephalus*, predation on three commercially important crab species in the eastern Bering Sea. Fish. Bull., U.S. 87:807-827.
- Livingston, P. A. 1991. Pacific cod. In P. A. Livingston (editor), Groundfish food habits and predation on commercially important prey species in the eastern Bering Sea from 1984 to 1986, p. 31-88. U.S. Dept. Commer., NOAA Tech. Memo. NMFS F/NWC-207.
- Low, L. L. 1974. A study of four major groundfish fisheries of the Bering Sea. Ph.D. Thesis, Univ. Washington, Seattle, WA 240 p.
- McAllister, M. K., and J. N. Ianelli. 1997. Bayesian stock assessment using catch-age data and the sampling-importance resampling algorithm. Can. J. Fish. Aquat. Sci. 54:284-300.
- Methot, R. D. 1986. Synthetic estimates of historical abundance and mortality for northern anchovy, *Engraulis mordax*. NMFS, Southwest Fish. Cent., Admin. Rep. LJ 86-29, La Jolla, CA.
- Methot, R. D. 1989. Synthetic estimates of historical abundance and mortality for northern anchovy. In E. Edwards and B. Megrey (editors), Mathematical analysis of fish stock dynamics: Reviews and current applications, p. 66-82. Amer. Fish. Soc. Symposium 6.
- Methot, R. D. 1990. Synthesis model: An adaptable framework for analysis of diverse stock assessment data. Int. N. Pac. Fish. Comm. Bull. 50:259-277.
- Methot, R. D. 1998. Application of stock synthesis to NRC test data sets. In V. R. Restrepo (editor), Analyses of simulated data sets in support of the NRC study on stock assessment methods, p. 59-80. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-F/SPO-30.
- Prentice, R. L. 1976. A generalization of the probit and logit methods for dose response curves. Biometrics 32:761-768.
- Ricker, W. E. 1954. Stock and recruitment. J. Fish. Res. Board Can. 11:559-63.
- Shimada, A. M., and D. K. Kimura. 1994. Seasonal movements of Pacific cod (*Gadus macrocephalus*) in the eastern Bering Sea and adjacent waters based on tag-recapture data. U.S. Natl. Mar. Fish. Serv., Fish. Bull. 92:800-816.
- Thompson, G. G., and M. W. Dorn. 1997. Pacific cod. In Plan Team for Groundfish Fisheries of the Bering Sea/Aleutian Islands (editor), Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions, p. 121-158. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.
- Thompson, G. G., and M. W. Dorn. 1998. Pacific cod. In Plan Team for Groundfish Fisheries of the Bering Sea/Aleutian Islands (editor), Stock assessment and fishery evaluation report for the groundfish

- resources of the Bering Sea/Aleutian Islands regions, p. 113-181. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.
- Thompson, G. G., and M. W. Dorn. 1999. Pacific cod. *In* Plan Team for Groundfish Fisheries of the Bering Sea/Aleutian Islands (editor), Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions, p. 151-230. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.
- Thompson, G. G., and M. K. Dorn. 2000. Pacific cod. *In* Plan Team for the Groundfish Fisheries of the Bering Sea and Aleutian Islands (compiler), Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands Regions, p. 189-212. North Pacific Fishery Management Council, 605 West 4th Ave., Suite 306, Anchorage, AK 99501.
- Thompson, G. G., and R. D. Methot. 1993. Pacific cod. *In* Plan Team for Groundfish Fisheries of the Bering Sea/Aleutian Islands (editor), Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands region as projected for 1994, chapter 2. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.
- Thompson, G. G., and A. M. Shimada. 1990. Pacific cod. *In* L. L. Low and R. E. Narita (editors), Condition of groundfish resources of the eastern Bering Sea-Aleutian Islands region as assessed in 1988, p. 44-66. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-178.
- Thompson, G. G., and H. H. Zenger. 1993. Pacific cod. *In* Plan Team for Groundfish Fisheries of the Gulf of Alaska (editor), Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska as projected for 1994, chapter 2. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.
- Thompson, G. G., and H. H. Zenger. 1995. Pacific cod. *In* Plan Team for the Groundfish Fisheries of the Gulf of Alaska (editor), Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska as projected for 1996, chapter 2. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.
- Thompson, G. G., H. H. Zenger, and M. W. Dorn. 1997. Pacific cod. *In* Plan Team for Groundfish Fisheries of the Gulf of Alaska (editor), Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 121-163. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.
- Thompson, G. G., H. H. Zenger, and M. W. Dorn. 1998. Pacific cod. *In* Plan Team for Groundfish Fisheries of the Gulf of Alaska (editor), Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 91-155. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.
- Thompson, G. G., H. H. Zenger, and M. W. Dorn. 1999. Pacific cod. *In* Plan Team for Groundfish Fisheries of the Gulf of Alaska (editor), Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 105-184. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.
- Walters, C. J., and D. Ludwig. 1981. Effects of measurement errors on the assessment of stock-recruitment relationships. *Can. J. Fish. Aquat. Sci.* 38:704-710.
- Wespestad, V., R. Bakkala, and J. June. 1982. Current abundance of Pacific cod (*Gadus macrocephalus*) in the eastern Bering Sea and expected abundance in 1982-1986. NOAA Tech. Memo. NMFS F/NWC-25, 26 p.
- Westrheim, S. J. 1996. On the Pacific cod (*Gadus macrocephalus*) in British Columbia waters, and a comparison with Pacific cod elsewhere, and Atlantic cod (*G. morhua*). *Can. Tech. Rep. Fish. Aquat. Sci.* 2092. 390 p.

Table 2.1--Summary of catches (t) of Pacific cod by management area, fleet sector, and gear type (page 1 of 3). All catches since 1980 include discards. LLine = longline, Subt. = sector subtotal. Catches for 2001 are through August. Catches by gear are not available prior to 1981.

**Eastern Bering Sea Only:**

| Year | Foreign      |              |              | Joint Venture |              | Domestic Annual Processing |              |            |              |              | Total  |
|------|--------------|--------------|--------------|---------------|--------------|----------------------------|--------------|------------|--------------|--------------|--------|
|      | <u>Trawl</u> | <u>LLine</u> | <u>Subt.</u> | <u>Trawl</u>  | <u>Subt.</u> | <u>Trawl</u>               | <u>LLine</u> | <u>Pot</u> | <u>Other</u> | <u>Subt.</u> |        |
| 1978 |              |              | 42512        |               | 0            |                            |              |            |              | 31           | 42543  |
| 1979 |              |              | 32981        |               | 0            |                            |              |            |              | 780          | 33761  |
| 1980 |              |              | 35058        |               | 8370         |                            |              |            |              | 2433         | 45861  |
| 1981 | 30347        | 5851         | 36198        | 7410          | 7410         | 12884                      | 1            | 0          | 14           | 12899        | 56507  |
| 1982 | 23037        | 3142         | 26179        | 9312          | 9312         | 23893                      | 5            | 0          | 1715         | 25613        | 61104  |
| 1983 | 32790        | 6445         | 39235        | 9662          | 9662         | 45310                      | 4            | 21         | 569          | 45904        | 94801  |
| 1984 | 30592        | 26642        | 57234        | 24382         | 24382        | 43274                      | 8            | 0          | 205          | 43487        | 125103 |
| 1985 | 19596        | 36742        | 56338        | 35634         | 35634        | 51425                      | 50           | 0          | 0            | 51475        | 143447 |
| 1986 | 13292        | 26563        | 39855        | 57827         | 57827        | 37646                      | 48           | 62         | 167          | 37923        | 135605 |
| 1987 | 7718         | 47028        | 54746        | 47722         | 47722        | 46039                      | 1395         | 1          | 0            | 47435        | 149903 |
| 1988 | 0            | 0            | 0            | 106592        | 106592       | 93706                      | 2474         | 299        | 0            | 96479        | 203071 |
| 1989 | 0            | 0            | 0            | 44612         | 44612        | 119631                     | 13935        | 145        | 0            | 133711       | 178323 |
| 1990 | 0            | 0            | 0            | 8078          | 8078         | 115493                     | 47114        | 1382       | 0            | 163989       | 172067 |
| 1991 | 0            | 0            | 0            | 0             | 0            | 129392                     | 76734        | 3343       | 0            | 209469       | 209469 |
| 1992 | 0            | 0            | 0            | 0             | 0            | 77259                      | 80168        | 7512       | 33           | 164972       | 164972 |
| 1993 | 0            | 0            | 0            | 0             | 0            | 81762                      | 49293        | 2098       | 2            | 133155       | 133155 |
| 1994 | 0            | 0            | 0            | 0             | 0            | 84931                      | 78563        | 8037       | 730          | 172261       | 172261 |
| 1995 | 0            | 0            | 0            | 0             | 0            | 110956                     | 97665        | 19275      | 599          | 228496       | 228496 |
| 1996 | 0            | 0            | 0            | 0             | 0            | 91910                      | 88882        | 28006      | 267          | 209064       | 209064 |
| 1997 | 0            | 0            | 0            | 0             | 0            | 93924                      | 117008       | 21493      | 173          | 232598       | 232598 |
| 1998 | 0            | 0            | 0            | 0             | 0            | 61145                      | 86140        | 13207      | 192          | 160684       | 160684 |
| 1999 | 0            | 0            | 0            | 0             | 0            | 51902                      | 81463        | 12399      | 100          | 145865       | 145865 |
| 2000 | 0            | 0            | 0            | 0             | 0            | 53815                      | 81640        | 15849      | 68           | 151372       | 151372 |
| 2001 | 0            | 0            | 0            | 0             | 0            | 29875                      | 45087        | 12173      | 52           | 87187        | 87187  |

Table 2.1--Summary of catches (t) of Pacific cod by management area, fleet sector, and gear type (page 2 of 3). All catches since 1980 include discards. LLine = longline, Subt. = sector subtotal. Catches for 2001 are through August. Catches by gear are not available prior to 1981.

**Aleutian Islands Region Only:**

| Year | Foreign      |              |              | Joint Venture |              | Domestic Annual Processing |              |            |              |              | Total |
|------|--------------|--------------|--------------|---------------|--------------|----------------------------|--------------|------------|--------------|--------------|-------|
|      | <u>Trawl</u> | <u>LLine</u> | <u>Subt.</u> | <u>Trawl</u>  | <u>Subt.</u> | <u>Trawl</u>               | <u>LLine</u> | <u>Pot</u> | <u>Other</u> | <u>Subt.</u> |       |
| 1978 |              |              | 0            |               | 0            |                            |              |            |              | 0            | 0     |
| 1979 |              |              | 0            |               | 0            |                            |              |            |              | 0            | 0     |
| 1980 |              |              | 0            |               | 86           |                            |              |            |              | 0            | 86    |
| 1981 | 2680         | 235          | 2915         | 1749          | 1749         | 2744                       | 26           | 0          | 0            | 2770         | 7434  |
| 1982 | 1520         | 476          | 1996         | 4280          | 4280         | 2121                       | 0            | 0          | 0            | 2121         | 8397  |
| 1983 | 1869         | 402          | 2271         | 4700          | 4700         | 1459                       | 0            | 0          | 0            | 1459         | 8430  |
| 1984 | 473          | 804          | 1277         | 6390          | 6390         | 314                        | 0            | 0          | 0            | 314          | 7981  |
| 1985 | 10           | 829          | 839          | 5638          | 5638         | 460                        | 0            | 0          | 0            | 460          | 6937  |
| 1986 | 5            | 0            | 5            | 6115          | 6115         | 784                        | 1            | 1          | 0            | 786          | 6906  |
| 1987 | 0            | 0            | 0            | 10435         | 10435        | 2662                       | 22           | 88         | 0            | 2772         | 13207 |
| 1988 | 0            | 0            | 0            | 3300          | 3300         | 1698                       | 137          | 30         | 0            | 1865         | 5165  |
| 1989 | 0            | 0            | 0            | 6             | 6            | 4233                       | 284          | 19         | 0            | 4536         | 4542  |
| 1990 | 0            | 0            | 0            | 0             | 0            | 6932                       | 602          | 7          | 0            | 7541         | 7541  |
| 1991 | 0            | 0            | 0            | 0             | 0            | 3414                       | 3203         | 3180       | 0            | 9797         | 9797  |
| 1992 | 0            | 0            | 0            | 0             | 0            | 14558                      | 22108        | 6317       | 84           | 43068        | 43068 |
| 1993 | 0            | 0            | 0            | 0             | 0            | 17312                      | 17693        | 0          | 33           | 35037        | 35037 |
| 1994 | 0            | 0            | 0            | 0             | 0            | 14382                      | 7009         | 147        | 0            | 21539        | 21539 |
| 1995 | 0            | 0            | 0            | 0             | 0            | 10574                      | 4935         | 1024       | 0            | 16534        | 16534 |
| 1996 | 0            | 0            | 0            | 0             | 0            | 21179                      | 5819         | 4611       | 0            | 31609        | 31609 |
| 1997 | 0            | 0            | 0            | 0             | 0            | 17349                      | 7151         | 575        | 89           | 25164        | 25164 |
| 1998 | 0            | 0            | 0            | 0             | 0            | 20757                      | 13782        | 425        | 0            | 34964        | 34964 |
| 1999 | 0            | 0            | 0            | 0             | 0            | 16437                      | 7874         | 3750       | 69           | 28130        | 28130 |
| 2000 | 0            | 0            | 0            | 0             | 0            | 0                          | 16183        | 20362      | 3139         | 39684        | 39684 |
| 2001 | 0            | 0            | 0            | 0             | 0            | 14488                      | 13664        | 397        | 19           | 28568        | 28568 |

Table 2.1--Summary of catches (t) of Pacific cod by management area, fleet sector, and gear type (page 3 of 3). All catches since 1980 include discards. LLine = longline, Subt. = sector subtotal. Catches for 2001 are through August. Catches by gear are not available prior to 1981.

**Eastern Bering Sea and Aleutian Islands Region Combined:**

| Year | Foreign      |              |              | Joint Venture |              | Domestic Annual Processing |              |            |              |              | Total  |
|------|--------------|--------------|--------------|---------------|--------------|----------------------------|--------------|------------|--------------|--------------|--------|
|      | <u>Trawl</u> | <u>LLine</u> | <u>Subt.</u> | <u>Trawl</u>  | <u>Subt.</u> | <u>Trawl</u>               | <u>LLine</u> | <u>Pot</u> | <u>Other</u> | <u>Subt.</u> |        |
| 1978 |              |              | 42512        |               | 0            |                            |              |            |              | 31           | 42543  |
| 1979 |              |              | 32981        |               | 0            |                            |              |            |              | 780          | 33761  |
| 1980 |              |              | 35058        |               | 8456         |                            |              |            |              | 2433         | 45947  |
| 1981 | 33027        | 6086         | 39113        | 9159          | 9159         | 15628                      | 27           | 0          | 14           | 15669        | 63941  |
| 1982 | 24557        | 3618         | 28175        | 13592         | 13592        | 26014                      | 5            | 0          | 1715         | 27734        | 69501  |
| 1983 | 34659        | 6847         | 41506        | 14362         | 14362        | 46769                      | 4            | 21         | 569          | 47363        | 103231 |
| 1984 | 31065        | 27446        | 58511        | 30772         | 30772        | 43588                      | 8            | 0          | 205          | 43801        | 133084 |
| 1985 | 19606        | 37571        | 57177        | 41272         | 41272        | 51885                      | 50           | 0          | 0            | 51935        | 150384 |
| 1986 | 13297        | 26563        | 39860        | 63942         | 63942        | 38430                      | 49           | 63         | 167          | 38709        | 142511 |
| 1987 | 7718         | 47028        | 54746        | 58157         | 58157        | 48701                      | 1417         | 89         | 0            | 50207        | 163110 |
| 1988 | 0            | 0            | 0            | 109892        | 109892       | 95404                      | 2611         | 329        | 0            | 98344        | 208236 |
| 1989 | 0            | 0            | 0            | 44618         | 44618        | 123864                     | 14219        | 164        | 0            | 138247       | 182865 |
| 1990 | 0            | 0            | 0            | 8078          | 8078         | 122425                     | 47716        | 1389       | 0            | 171530       | 179608 |
| 1991 | 0            | 0            | 0            | 0             | 0            | 132806                     | 79937        | 6523       | 0            | 219266       | 219266 |
| 1992 | 0            | 0            | 0            | 0             | 0            | 91818                      | 102276       | 13829      | 117          | 208039       | 208039 |
| 1993 | 0            | 0            | 0            | 0             | 0            | 99074                      | 66986        | 2098       | 35           | 168192       | 168192 |
| 1994 | 0            | 0            | 0            | 0             | 0            | 99313                      | 85573        | 8184       | 730          | 193800       | 193800 |
| 1995 | 0            | 0            | 0            | 0             | 0            | 121530                     | 102600       | 20299      | 599          | 245029       | 245029 |
| 1996 | 0            | 0            | 0            | 0             | 0            | 113089                     | 94701        | 32617      | 267          | 240673       | 240673 |
| 1997 | 0            | 0            | 0            | 0             | 0            | 111273                     | 124159       | 22068      | 262          | 257762       | 257762 |
| 1998 | 0            | 0            | 0            | 0             | 0            | 81903                      | 99921        | 13632      | 192          | 195648       | 195648 |
| 1999 | 0            | 0            | 0            | 0             | 0            | 68339                      | 89337        | 16150      | 169          | 173995       | 173995 |
| 2000 | 0            | 0            | 0            | 0             | 0            | 53815                      | 97823        | 36210      | 3207         | 191056       | 191056 |
| 2001 | 0            | 0            | 0            | 0             | 0            | 44364                      | 58751        | 12570      | 71           | 115756       | 115756 |

Table 2.2--History of Pacific cod ABC, TAC, total BSAI catch, and type of stock assessment model used to recommend ABC. Catch for 2001 is current through August.

| Year | ABC     | TAC     | Catch   | Stock Assessment Model                        |
|------|---------|---------|---------|---|
| 1980 | 148,000 | 70,700  | 45,947  | projection of 1979 survey numbers at age      |
| 1981 | 160,000 | 78,700  | 63,941  | projection of 1979 survey numbers at age      |
| 1982 | 168,000 | 78,700  | 69,501  | projection of 1979 survey numbers at age      |
| 1983 | 298,200 | 120,000 | 103,231 | projection of 1979 survey numbers at age      |
| 1984 | 291,300 | 210,000 | 133,084 | projection of 1979 survey numbers at age      |
| 1985 | 347,400 | 220,000 | 150,384 | projection of 1979-1985 survey numbers at age |
| 1986 | 249,300 | 229,000 | 142,511 | separable age-structured model                |
| 1987 | 400,000 | 280,000 | 163,110 | separable age-structured model                |
| 1988 | 385,300 | 200,000 | 208,236 | separable age-structured model                |
| 1989 | 370,600 | 230,681 | 182,865 | separable age-structured model                |
| 1990 | 417,000 | 227,000 | 179,608 | separable age-structured model                |
| 1991 | 229,000 | 229,000 | 219,266 | separable age-structured model                |
| 1992 | 182,000 | 182,000 | 208,039 | age-structured Synthesis model                |
| 1993 | 164,500 | 164,500 | 168,192 | length-structured Synthesis model             |
| 1994 | 191,000 | 191,000 | 193,800 | length-structured Synthesis model             |
| 1995 | 328,000 | 250,000 | 245,029 | length-structured Synthesis model             |
| 1996 | 305,000 | 270,000 | 240,673 | length-structured Synthesis model             |
| 1997 | 306,000 | 270,000 | 257,762 | length-structured Synthesis model             |
| 1998 | 210,000 | 210,000 | 195,648 | length-structured Synthesis model             |
| 1999 | 177,000 | 177,000 | 173,995 | length-structured Synthesis model             |
| 2000 | 193,000 | 193,000 | 191,056 | length-structured Synthesis model             |
| 2001 | 188,000 | 188,000 | 115,756 | length-structured Synthesis model             |

Table 2.3--Discarded and retained catch of Pacific cod in the 2000 and 2001 fisheries, expressed in both absolute and relative terms. For data expressed in absolute terms, the discarded and retained catches in each row sum to the total catch (t) for the respective target. For data expressed in relative terms, the discarded and retained catches in each row sum to 1.0. For each portion of the table, data are sorted in descending order of the “discarded” column. Data for 2001 are through October 6.

| Catch for year 2000 expressed in absolute terms |           |          | Catch for year 2000 expressed in relative terms |           |          |
|---|-----------|----------|---|-----------|----------|
| Target  | Discarded | Retained | Target  | Discarded | Retained |
| Pacific cod                                     | 3150      | 168389   | no retained groundfish                          | 0.789     | 0.211    |
| yellowfin sole                                  | 316       | 4876     | sablefish                                       | 0.414     | 0.586    |
| midwater pollock                                | 161       | 2905     | Greenland turbot                                | 0.192     | 0.808    |
| rock sole                                       | 113       | 4106     | other   | 0.152     | 0.848    |
| flathead sole                                   | 71        | 3639     | yellowfin sole                                  | 0.061     | 0.939    |
| sablefish                                       | 43        | 61       | midwater pollock                                | 0.052     | 0.948    |
| Greenland turbot                                | 43        | 180      | bottom pollock                                  | 0.048     | 0.952    |
| Atka mackerel                                   | 30        | 2091     | rock sole                                       | 0.027     | 0.973    |
| bottom pollock                                  | 18        | 349      | arrowtooth flounder                             | 0.023     | 0.977    |
| no retained groundfish                          | 4         | 1        | flathead sole                                   | 0.019     | 0.981    |
| other   | 3         | 18       | Pacific cod                                     | 0.018     | 0.982    |
| other flatfish                                  | 3         | 290      | Atka mackerel                                   | 0.014     | 0.986    |
| arrowtooth flounder                             | 2         | 79       | other flatfish                                  | 0.010     | 0.990    |
| rockfish (all species)                          | 0         | 117      | rockfish (all species)                          | 0.001     | 0.999    |
| all   | 3956      | 187101   | all   | 0.021     | 0.979    |

| Catch for year 2001 expressed in absolute terms |           |          | Catch for year 2001 expressed in relative terms |           |          |
|---|-----------|----------|---|-----------|----------|
| Target  | Discarded | Retained | Target  | Discarded | Retained |
| Pacific cod                                     | 1645      | 120886   | no retained groundfish                          | 1.000     | 0.000    |
| rock sole                                       | 166       | 3224     | sablefish                                       | 0.092     | 0.908    |
| yellowfin sole                                  | 115       | 4374     | other   | 0.081     | 0.919    |
| flathead sole                                   | 99        | 2708     | rock sole                                       | 0.049     | 0.951    |
| midwater pollock                                | 34        | 3168     | flathead sole                                   | 0.035     | 0.965    |
| Atka mackerel                                   | 9         | 1830     | yellowfin sole                                  | 0.026     | 0.974    |
| bottom pollock                                  | 8         | 302      | bottom pollock                                  | 0.024     | 0.976    |
| sablefish                                       | 7         | 68       | arrowtooth flounder                             | 0.019     | 0.981    |
| no retained groundfish                          | 6         | 0        | Pacific cod                                     | 0.013     | 0.987    |
| arrowtooth flounder                             | 4         | 194      | midwater pollock                                | 0.011     | 0.989    |
| other   | 4         | 43       | Greenland turbot                                | 0.005     | 0.995    |
| Greenland turbot                                | 1         | 114      | Atka mackerel                                   | 0.005     | 0.995    |
| rockfish (all species)                          | 0         | 196      | rockfish (all species)                          | 0.001     | 0.999    |
| other flatfish                                  | 0         | 71       | other flatfish                                  | 0.000     | 1.000    |
| all   | 2096      | 137178   | all   | 0.015     | 0.985    |

Table 2.4--Catch (t) of Pacific cod by year, gear, and period. Catch for 2001 is complete through period 2. Distribution of catch for 1978-1980 by gear and period was estimated from other years' data.

| Year | Trawl    |          |          | Longline |          |          | Pot      |          |          |
|------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
|      | Period 1 | Period 2 | Period 3 | Period 1 | Period 2 | Period 3 | Period 1 | Period 2 | Period 3 |
| 1978 | 10424    | 11288    | 18021    | 1371     | 1032     | 1856     | 0        | 0        | 0        |
| 1979 | 10397    | 12587    | 10403    | 1371     | 699      | 547      | 0        | 0        | 0        |
| 1980 | 9452     | 9007     | 17039    | 1106     | 206      | 4230     | 0        | 0        | 0        |
| 1981 | 15067    | 14087    | 21486    | 1286     | 624      | 3942     | 0        | 0        | 0        |
| 1982 | 21742    | 18151    | 16348    | 363      | 475      | 2308     | 0        | 0        | 0        |
| 1983 | 40757    | 24300    | 22705    | 2941     | 748      | 2756     | 0        | 0        | 0        |
| 1984 | 48237    | 24964    | 25045    | 5012     | 2128     | 19508    | 0        | 0        | 0        |
| 1985 | 55673    | 28673    | 22310    | 13703    | 1710     | 21379    | 0        | 0        | 0        |
| 1986 | 59786    | 26598    | 22382    | 8895     | 438      | 17278    | 0        | 0        | 0        |
| 1987 | 64413    | 15604    | 21462    | 20947    | 723      | 26752    | 0        | 0        | 0        |
| 1988 | 127470   | 25662    | 47166    | 444      | 646      | 1385     | 90       | 51       | 160      |
| 1989 | 127459   | 16986    | 19798    | 3810     | 4968     | 5157     | 33       | 63       | 49       |
| 1990 | 101645   | 11402    | 10524    | 13171    | 16643    | 17299    | 0        | 986      | 395      |
| 1991 | 107979   | 15549    | 5863     | 25470    | 21472    | 29792    | 12       | 1042     | 2288     |
| 1992 | 59460    | 11840    | 5959     | 49696    | 24195    | 6276     | 2622     | 4632     | 258      |
| 1993 | 67120    | 5362     | 9280     | 49242    | 27       | 23       | 2073     | 24       | 0        |
| 1994 | 61009    | 5806     | 18115    | 57968    | 13       | 20582    | 4923     | 0        | 3113     |
| 1995 | 90366    | 8543     | 12047    | 68458    | 26       | 29180    | 12484    | 3469     | 3322     |
| 1996 | 78194    | 3126     | 10590    | 62011    | 26       | 26845    | 18143    | 6401     | 3462     |
| 1997 | 81313    | 3927     | 8684     | 70676    | 43       | 46290    | 14584    | 3576     | 3333     |
| 1998 | 45130    | 5629     | 10386    | 54219    | 27       | 31893    | 9022     | 2779     | 1407     |
| 1999 | 44904    | 3312     | 3686     | 55180    | 1923     | 24360    | 9346     | 1001     | 2052     |
| 2000 | 44508    | 4578     | 4730     | 40180    | 1375     | 40086    | 15742    | 0        | 107      |
| 2001 | 22849    | 7026     |          | 38370    | 6717     |          | 11731    | 442      |          |

Table 2.5--Pacific cod length sample sizes from the commercial fisheries.

| Year | Trawl Fishery |               |               | Longline Fishery |               |               | Pot Fishery   |               |               |
|------|---------------|---------------|---------------|------------------|---------------|---------------|---------------|---------------|---------------|
|      | <u>Per. 1</u> | <u>Per. 2</u> | <u>Per. 3</u> | <u>Per. 1</u>    | <u>Per. 2</u> | <u>Per. 3</u> | <u>Per. 1</u> | <u>Per. 2</u> | <u>Per. 3</u> |
| 1978 | 646           | 0             | 3161          | 2885             | 4886          | 2514          | 0             | 0             | 0             |
| 1979 | 1667          | 0             | 748           | 11410            | 2514          | 2662          | 0             | 0             | 0             |
| 1980 | 1359          | 73            | 327           | 2600             | 1389          | 2932          | 0             | 0             | 0             |
| 1981 | 132           | 0             | 1540          | 2253             | 1276          | 1300          | 0             | 0             | 0             |
| 1982 | 592           | 226           | 1643          | 2910             | 1203          | 5078          | 0             | 0             | 0             |
| 1983 | 12386         | 1231          | 14577         | 18800            | 4119          | 9610          | 0             | 0             | 0             |
| 1984 | 10246         | 4482          | 4477          | 6853             | 6004          | 82103         | 0             | 0             | 0             |
| 1985 | 30171         | 1556          | 3051          | 0                | 4561          | 134469        | 0             | 0             | 0             |
| 1986 | 28566         | 1813          | 2548          | 18588            | 200           | 104142        | 0             | 0             | 0             |
| 1987 | 46360         | 6674          | 20923         | 70273            | 0             | 165124        | 0             | 0             | 0             |
| 1988 | 103453        | 0             | 2897          | 0                | 0             | 0             | 0             | 0             | 0             |
| 1989 | 58575         | 612           | 669           | 0                | 0             | 0             | 0             | 0             | 0             |
| 1990 | 64143         | 9807          | 250           | 18900            | 74534         | 62550         | 0             | 1506          | 5772          |
| 1991 | 88727         | 2083          | 0             | 54671            | 70808         | 91693         | 0             | 10701         | 11243         |
| 1992 | 79286         | 0             | 0             | 152152           | 134263        | 20129         | 17289         | 48569         | 5147          |
| 1993 | 81637         | 0             | 0             | 154337           | 0             | 0             | 10557         | 0             | 0             |
| 1994 | 103839        | 0             | 0             | 172585           | 0             | 45350         | 25950         | 0             | 6436          |
| 1995 | 68575         | 0             | 0             | 144739           | 392           | 74766         | 47660         | 16786         | 13741         |
| 1996 | 104295        | 1139          | 3473          | 164051           | 156           | 75385         | 76393         | 23063         | 11199         |
| 1997 | 106847        | 275           | 0             | 184741           | 109           | 144489        | 43859         | 11760         | 11760         |
| 1998 | 108187        | 2790          | 2974          | 162821           | 62            | 190555        | 26595         | 8899          | 4522          |
| 1999 | 44845         | 228           | 1136          | 84227            | 10095         | 51065         | 22634         | 1875          | 8922          |
| 2000 | 47085         | 304           | 67            | 71413            | 9960          | 97697         | 26040         | 0             | 512           |
| 2001 | 25160         | 1631          | 0             | 84578            | 7042          | 0             | 14677         | 239           | 0             |

Table 2.6—Length frequencies of Pacific cod in the pre-1989 trawl fishery by year, period, and length bin.

| Yr.  | Per | Length Bin |          |          |          |          |          |          |          |          |           |           |           |           |           |           |           |           |           |           |           |           |           |           |           |           |
|------|-----|------------|----------|----------|----------|----------|----------|----------|----------|----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
|      |     | <u>1</u>   | <u>2</u> | <u>3</u> | <u>4</u> | <u>5</u> | <u>6</u> | <u>7</u> | <u>8</u> | <u>9</u> | <u>10</u> | <u>11</u> | <u>12</u> | <u>13</u> | <u>14</u> | <u>15</u> | <u>16</u> | <u>17</u> | <u>18</u> | <u>19</u> | <u>20</u> | <u>21</u> | <u>22</u> | <u>23</u> | <u>24</u> | <u>25</u> |
| 1978 | 1   | 0          | 0        | 0        | 1        | 1        | 1        | 1        | 2        | 5        | 22        | 29        | 88        | 233       | 112       | 44        | 32        | 36        | 15        | 11        | 9         | 1         | 1         | 2         | 0         | 0         |
| 1978 | 3   | 0          | 0        | 0        | 0        | 0        | 6        | 35       | 79       | 37       | 21        | 19        | 5         | 62        | 387       | 999       | 882       | 337       | 159       | 81        | 37        | 13        | 2         | 0         | 0         | 0         |
| 1979 | 1   | 0          | 0        | 0        | 0        | 0        | 2        | 1        | 21       | 46       | 94        | 206       | 319       | 346       | 100       | 149       | 161       | 152       | 48        | 11        | 4         | 5         | 1         | 1         | 0         | 0         |
| 1979 | 3   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 3        | 5        | 24        | 74        | 150       | 220       | 78        | 38        | 47        | 58        | 31        | 14        | 4         | 0         | 0         | 0         | 1         | 1         |
| 1980 | 1   | 0          | 0        | 0        | 0        | 0        | 0        | 1        | 10       | 34       | 84        | 186       | 295       | 462       | 192       | 49        | 19        | 14        | 8         | 3         | 1         | 1         | 0         | 0         | 0         | 0         |
| 1980 | 2   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0         | 0         | 0         | 1         | 16        | 45        | 8         | 3         | 0         | 0         | 0         | 0         | 0         | 0         | 0         | 0         |
| 1980 | 3   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 1        | 0        | 0         | 9         | 17        | 37        | 79        | 70        | 55        | 32        | 8         | 9         | 6         | 3         | 0         | 1         | 0         | 0         |
| 1981 | 1   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0         | 0         | 8         | 28        | 43        | 34        | 16        | 3         | 0         | 0         | 0         | 0         | 0         | 0         | 0         | 0         |
| 1981 | 3   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 2        | 1        | 0         | 3         | 8         | 26        | 122       | 336       | 373       | 301       | 194       | 120       | 32        | 13        | 7         | 2         | 0         | 0         |
| 1982 | 1   | 0          | 0        | 0        | 0        | 0        | 1        | 1        | 4        | 21       | 22        | 9         | 13        | 48        | 61        | 94        | 133       | 84        | 69        | 20        | 8         | 3         | 1         | 0         | 0         | 0         |
| 1982 | 2   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 1         | 1         | 7         | 21        | 14        | 21        | 41        | 43        | 33        | 16        | 13        | 4         | 6         | 4         | 1         | 0         |
| 1982 | 3   | 0          | 0        | 0        | 0        | 0        | 0        | 1        | 0        | 0        | 1         | 4         | 27        | 70        | 143       | 215       | 196       | 302       | 346       | 215       | 90        | 18        | 9         | 5         | 1         | 0         |
| 1983 | 1   | 0          | 0        | 0        | 0        | 0        | 5        | 20       | 99       | 286      | 284       | 275       | 467       | 1113      | 1272      | 1978      | 2477      | 1982      | 1193      | 584       | 202       | 72        | 35        | 22        | 13        | 7         |
| 1983 | 2   | 0          | 0        | 0        | 0        | 0        | 1        | 0        | 1        | 3        | 10        | 4         | 7         | 31        | 95        | 204       | 289       | 249       | 187       | 85        | 30        | 11        | 8         | 6         | 7         | 3         |
| 1983 | 3   | 0          | 0        | 0        | 0        | 1        | 15       | 24       | 26       | 15       | 8         | 35        | 205       | 421       | 508       | 1451      | 1999      | 2487      | 2441      | 2235      | 1563      | 767       | 284       | 66        | 21        | 5         |
| 1984 | 1   | 0          | 1        | 1        | 1        | 0        | 7        | 121      | 251      | 222      | 132       | 66        | 148       | 439       | 503       | 758       | 1394      | 2027      | 1873      | 1278      | 639       | 263       | 96        | 16        | 9         | 1         |
| 1984 | 2   | 0          | 1        | 0        | 0        | 5        | 18       | 14       | 5        | 10       | 55        | 93        | 118       | 241       | 284       | 403       | 612       | 638       | 620       | 481       | 411       | 313       | 110       | 42        | 7         | 1         |
| 1984 | 3   | 0          | 0        | 0        | 0        | 0        | 7        | 21       | 15       | 114      | 434       | 370       | 188       | 137       | 124       | 254       | 396       | 576       | 614       | 483       | 376       | 224       | 99        | 32        | 13        | 0         |
| 1985 | 1   | 0          | 0        | 2        | 0        | 4        | 0        | 2        | 39       | 116      | 262       | 733       | 1768      | 2246      | 1088      | 1415      | 2474      | 5067      | 5635      | 4340      | 2649      | 1402      | 608       | 229       | 69        | 23        |
| 1985 | 2   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 3        | 24       | 77        | 70        | 119       | 425       | 356       | 116       | 59        | 70        | 88        | 73        | 35        | 20        | 8         | 9         | 3         | 1         |
| 1985 | 3   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 1        | 0        | 9         | 79        | 170       | 533       | 322       | 195       | 126       | 288       | 424       | 374       | 296       | 152       | 78        | 4         | 0         | 0         |
| 1986 | 1   | 0          | 4        | 16       | 8        | 34       | 62       | 118      | 249      | 636      | 761       | 683       | 788       | 2229      | 3564      | 3293      | 2108      | 2647      | 3498      | 3377      | 2446      | 1346      | 456       | 168       | 58        | 17        |
| 1986 | 2   | 0          | 0        | 0        | 0        | 0        | 0        | 7        | 4        | 2        | 4         | 5         | 9         | 26        | 95        | 130       | 195       | 285       | 481       | 352       | 128       | 48        | 30        | 8         | 4         | 0         |
| 1986 | 3   | 0          | 0        | 1        | 0        | 0        | 0        | 2        | 1        | 15       | 17        | 28        | 26        | 86        | 169       | 288       | 405       | 520       | 406       | 265       | 136       | 93        | 59        | 22        | 4         | 5         |
| 1987 | 1   | 0          | 0        | 3        | 13       | 15       | 58       | 194      | 446      | 516      | 640       | 1250      | 2235      | 4300      | 3164      | 3663      | 6190      | 6238      | 5028      | 4338      | 3669      | 2326      | 1255      | 510       | 234       | 75        |
| 1987 | 2   | 0          | 0        | 0        | 0        | 1        | 1        | 2        | 5        | 9        | 6         | 10        | 29        | 135       | 241       | 422       | 837       | 1294      | 1344      | 889       | 574       | 397       | 252       | 133       | 68        | 25        |
| 1987 | 3   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 7        | 13        | 68        | 76        | 263       | 1095      | 1809      | 2177      | 2736      | 3204      | 2732      | 2087      | 1946      | 1549      | 802       | 306       | 53        |
| 1988 | 1   | 1          | 0        | 1        | 1        | 6        | 30       | 93       | 605      | 1533     | 2081      | 2311      | 4634      | 11994     | 11361     | 10890     | 9690      | 10862     | 13124     | 11333     | 6319      | 3330      | 1855      | 913       | 380       | 106       |
| 1988 | 3   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 5        | 0         | 13        | 52        | 257       | 326       | 284       | 348       | 348       | 373       | 332       | 305       | 166       | 56        | 20        | 6         | 6         |

Table 2.7—Length frequencies of Pacific cod in the pre-1989 longline fishery by year, period, and length bin.

| Yr.  | Per | Length Bin |          |          |          |          |          |          |          |          |           |           |           |           |           |           |           |           |           |           |           |           |           |           |           |           |
|------|-----|------------|----------|----------|----------|----------|----------|----------|----------|----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
|      |     | <u>1</u>   | <u>2</u> | <u>3</u> | <u>4</u> | <u>5</u> | <u>6</u> | <u>7</u> | <u>8</u> | <u>9</u> | <u>10</u> | <u>11</u> | <u>12</u> | <u>13</u> | <u>14</u> | <u>15</u> | <u>16</u> | <u>17</u> | <u>18</u> | <u>19</u> | <u>20</u> | <u>21</u> | <u>22</u> | <u>23</u> | <u>24</u> | <u>25</u> |
| 1978 | 1   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 1        | 4         | 23        | 124       | 623       | 812       | 435       | 269       | 216       | 160       | 110       | 58        | 36        | 7         | 7         | 0         | 0         |
| 1978 | 2   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 1         | 7         | 40        | 240       | 574       | 1226      | 994       | 716       | 566       | 330       | 133       | 44        | 12        | 2         | 1         | 0         |
| 1978 | 3   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0         | 2         | 0         | 62        | 366       | 736       | 788       | 306       | 124       | 66        | 35        | 19        | 8         | 2         | 0         | 0         |
| 1979 | 1   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 8        | 83       | 377       | 683       | 436       | 375       | 1303      | 2454      | 2711      | 1575      | 679       | 380       | 208       | 87        | 36        | 8         | 7         | 0         |
| 1979 | 2   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 2        | 14        | 49        | 90        | 155       | 102       | 327       | 646       | 660       | 315       | 86        | 43        | 17        | 5         | 3         | 0         | 0         |
| 1979 | 3   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 2         | 10        | 47        | 233       | 249       | 174       | 387       | 683       | 599       | 216       | 41        | 10        | 9         | 2         | 0         | 0         |
| 1980 | 1   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 5        | 15        | 66        | 212       | 591       | 604       | 320       | 182       | 199       | 244       | 111       | 36        | 11        | 4         | 0         | 0         | 0         |
| 1980 | 2   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0         | 1         | 29        | 169       | 334       | 293       | 185       | 148       | 140       | 67        | 17        | 4         | 2         | 0         | 0         | 0         |
| 1980 | 3   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0         | 1         | 18        | 235       | 558       | 679       | 652       | 350       | 194       | 138       | 76        | 25        | 5         | 0         | 1         | 0         |
| 1981 | 1   | 0          | 0        | 0        | 0        | 5        | 18       | 7        | 7        | 10       | 0         | 18        | 48        | 285       | 503       | 453       | 340       | 198       | 153       | 89        | 70        | 36        | 9         | 4         | 0         | 0         |
| 1981 | 2   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 2        | 1         | 8         | 29        | 88        | 160       | 265       | 292       | 228       | 108       | 35        | 32        | 24        | 3         | 1         | 0         | 0         |
| 1981 | 3   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0         | 0         | 2         | 8         | 86        | 230       | 318       | 300       | 220       | 89        | 29        | 15        | 2         | 0         | 1         | 0         |
| 1982 | 1   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 1        | 1        | 14        | 22        | 30        | 215       | 381       | 520       | 550       | 468       | 298       | 167       | 100       | 78        | 47        | 13        | 3         | 2         |
| 1982 | 2   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 9         | 43        | 17        | 102       | 208       | 164       | 211       | 164       | 133       | 80        | 48        | 11        | 7         | 3         | 3         | 0         |
| 1982 | 3   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 1        | 0        | 1         | 15        | 35        | 107       | 270       | 512       | 830       | 1195      | 1101      | 639       | 240       | 82        | 35        | 9         | 4         | 2         |
| 1983 | 1   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 1        | 3        | 21        | 51        | 178       | 1231      | 1673      | 2160      | 2944      | 3606      | 3254      | 2018      | 876       | 390       | 220       | 117       | 48        | 9         |
| 1983 | 2   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 1        | 4         | 18        | 24        | 118       | 414       | 454       | 580       | 676       | 704       | 520       | 368       | 154       | 55        | 19        | 10        | 0         |
| 1983 | 3   | 0          | 0        | 0        | 0        | 0        | 0        | 1        | 0        | 0        | 0         | 4         | 28        | 129       | 459       | 1163      | 1262      | 1550      | 1779      | 1565      | 993       | 477       | 148       | 37        | 9         | 6         |
| 1984 | 1   | 0          | 0        | 0        | 0        | 0        | 1        | 0        | 4        | 11       | 21        | 22        | 20        | 191       | 414       | 614       | 1188      | 1473      | 1370      | 833       | 400       | 177       | 60        | 31        | 20        | 3         |
| 1984 | 2   | 0          | 0        | 0        | 0        | 0        | 2        | 0        | 0        | 2        | 3         | 10        | 8         | 54        | 232       | 468       | 960       | 1290      | 1095      | 774       | 524       | 374       | 158       | 36        | 11        | 3         |
| 1984 | 3   | 0          | 0        | 0        | 0        | 0        | 0        | 1        | 2        | 12       | 53        | 250       | 643       | 1558      | 2738      | 6857      | 12095     | 15376     | 15438     | 12475     | 8243      | 4156      | 1555      | 465       | 143       | 43        |
| 1985 | 2   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 1         | 3         | 25        | 221       | 348       | 177       | 346       | 628       | 849       | 710       | 526       | 392       | 216       | 96        | 21        | 2         |
| 1985 | 3   | 0          | 0        | 0        | 0        | 0        | 1        | 0        | 0        | 5        | 28        | 167       | 756       | 5832      | 16308     | 14473     | 11108     | 18384     | 25332     | 19838     | 11750     | 6227      | 2938      | 1006      | 252       | 64        |
| 1986 | 1   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 7        | 23       | 51        | 84        | 278       | 1093      | 1464      | 1354      | 1181      | 2186      | 3783      | 3595      | 2082      | 911       | 360       | 107       | 26        | 3         |
| 1986 | 2   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0         | 0         | 0         | 0         | 19        | 29        | 47        | 23        | 21        | 32        | 14        | 9         | 3         | 3         | 0         | 0         |
| 1986 | 3   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 18        | 154       | 610       | 2194      | 5080      | 14156     | 23223     | 20331     | 10705     | 10312     | 8875      | 4920      | 2286      | 869       | 324       | 85        |
| 1987 | 1   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 1        | 10       | 38        | 291       | 983       | 3411      | 3420      | 5818      | 10732     | 12540     | 10019     | 9453      | 7603      | 3871      | 1490      | 422       | 145       | 26        |
| 1987 | 3   | 0          | 0        | 0        | 3        | 0        | 0        | 0        | 2        | 7        | 26        | 130       | 511       | 4041      | 17126     | 27487     | 22822     | 24411     | 26687     | 19727     | 10159     | 6334      | 3638      | 1480      | 399       | 134       |

Table 2.8—Length frequencies of Pacific cod in the post-1988 trawl fishery by year, period, and length bin.

| Yr.  | Per | Length Bin |          |          |          |          |          |          |          |          |           |           |           |           |           |           |           |           |           |           |           |           |           |           |           |           |
|------|-----|------------|----------|----------|----------|----------|----------|----------|----------|----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
|      |     | <u>1</u>   | <u>2</u> | <u>3</u> | <u>4</u> | <u>5</u> | <u>6</u> | <u>7</u> | <u>8</u> | <u>9</u> | <u>10</u> | <u>11</u> | <u>12</u> | <u>13</u> | <u>14</u> | <u>15</u> | <u>16</u> | <u>17</u> | <u>18</u> | <u>19</u> | <u>20</u> | <u>21</u> | <u>22</u> | <u>23</u> | <u>24</u> | <u>25</u> |
| 1989 | 1   | 0          | 0        | 3        | 3        | 1        | 0        | 29       | 217      | 497      | 799       | 721       | 961       | 3128      | 4368      | 4678      | 5713      | 7070      | 8599      | 8291      | 6310      | 3853      | 1882      | 917       | 391       | 144       |
| 1989 | 2   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 1        | 0         | 4         | 3         | 20        | 68        | 109       | 136       | 142       | 79        | 39        | 9         | 1         | 0         | 1         | 0         | 0         |
| 1989 | 3   | 0          | 0        | 0        | 0        | 1        | 6        | 7        | 13       | 32       | 53        | 49        | 33        | 90        | 54        | 36        | 83        | 92        | 88        | 22        | 6         | 4         | 0         | 0         | 0         | 0         |
| 1990 | 1   | 0          | 0        | 3        | 4        | 14       | 85       | 312      | 710      | 953      | 888       | 715       | 539       | 1148      | 2576      | 4417      | 7339      | 9969      | 10306     | 9376      | 6405      | 4195      | 2266      | 1280      | 480       | 163       |
| 1990 | 2   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 2        | 2        | 6         | 6         | 17        | 106       | 377       | 772       | 1048      | 1631      | 1566      | 1623      | 1221      | 655       | 457       | 206       | 80        | 32        |
| 1990 | 3   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 1        | 2         | 14        | 42        | 13        | 30        | 17        | 16        | 49        | 17        | 19        | 16        | 10        | 0         | 2         | 0         | 2         |
| 1991 | 1   | 0          | 1        | 5        | 6        | 15       | 71       | 452      | 1230     | 1329     | 1232      | 1288      | 1713      | 5172      | 6133      | 6560      | 9202      | 12298     | 12683     | 10962     | 7771      | 5103      | 2937      | 1517      | 766       | 281       |
| 1991 | 2   | 1          | 0        | 1        | 1        | 2        | 2        | 7        | 9        | 16       | 32        | 25        | 27        | 103       | 129       | 216       | 251       | 300       | 319       | 219       | 200       | 136       | 62        | 18        | 1         | 6         |
| 1992 | 1   | 0          | 3        | 9        | 15       | 21       | 67       | 200      | 631      | 1310     | 1664      | 2488      | 4704      | 9607      | 7198      | 6648      | 6782      | 8239      | 8016      | 7777      | 5712      | 3853      | 2326      | 1291      | 517       | 208       |
| 1993 | 1   | 0          | 0        | 5        | 8        | 23       | 56       | 254      | 1164     | 1666     | 1780      | 4496      | 7742      | 11709     | 10367     | 9951      | 7408      | 5314      | 4343      | 3901      | 3540      | 3128      | 2163      | 1472      | 806       | 341       |
| 1994 | 1   | 0          | 1        | 5        | 5        | 24       | 106      | 610      | 2149     | 3791     | 3227      | 1938      | 2981      | 9909      | 14285     | 14434     | 11718     | 11710     | 9933      | 6337      | 4075      | 2739      | 1764      | 1161      | 623       | 314       |
| 1995 | 1   | 0          | 0        | 12       | 28       | 46       | 160      | 306      | 448      | 495      | 707       | 2597      | 5806      | 9110      | 5979      | 7066      | 8171      | 8721      | 7021      | 4381      | 2782      | 1824      | 1195      | 772       | 540       | 408       |
| 1996 | 1   | 1          | 6        | 13       | 25       | 29       | 51       | 382      | 1066     | 1319     | 1118      | 1145      | 2429      | 8755      | 14699     | 13711     | 9877      | 10959     | 11919     | 9647      | 6868      | 4308      | 2875      | 1607      | 911       | 575       |
| 1996 | 2   | 0          | 0        | 0        | 0        | 0        | 0        | 2        | 2        | 5        | 10        | 11        | 35        | 112       | 164       | 186       | 106       | 125       | 97        | 160       | 107       | 16        | 0         | 0         | 1         | 0         |
| 1996 | 3   | 0          | 0        | 0        | 0        | 0        | 0        | 1        | 0        | 3        | 1         | 13        | 51        | 132       | 149       | 275       | 322       | 292       | 287       | 305       | 436       | 454       | 388       | 220       | 104       | 40        |
| 1997 | 1   | 1          | 4        | 17       | 80       | 97       | 65       | 326      | 1261     | 2372     | 2398      | 1778      | 2027      | 7423      | 8553      | 11653     | 16352     | 16489     | 12167     | 7909      | 5444      | 4105      | 2800      | 1846      | 1060      | 620       |
| 1997 | 2   | 0          | 1        | 0        | 4        | 5        | 1        | 4        | 4        | 8        | 8         | 12        | 13        | 31        | 42        | 38        | 34        | 20        | 24        | 15        | 8         | 2         | 0         | 0         | 1         | 0         |
| 1998 | 1   | 0          | 1        | 7        | 4        | 7        | 114      | 744      | 1464     | 1423     | 1113      | 969       | 1398      | 5031      | 6020      | 6694      | 10192     | 14965     | 16533     | 10659     | 5972      | 3531      | 2880      | 2293      | 1631      | 1107      |
| 1998 | 2   | 0          | 0        | 0        | 0        | 1        | 0        | 0        | 1        | 31       | 61        | 71        | 47        | 110       | 242       | 298       | 270       | 195       | 125       | 83        | 36        | 12        | 9         | 5         | 10        | 6         |
| 1998 | 3   | 0          | 0        | 0        | 0        | 0        | 0        | 1        | 2        | 3        | 12        | 37        | 60        | 135       | 172       | 249       | 177       | 190       | 211       | 258       | 270       | 160       | 74        | 68        | 46        | 22        |
| 1999 | 1   | 4          | 0        | 1        | 6        | 5        | 10       | 108      | 421      | 412      | 382       | 1039      | 2515      | 5006      | 3143      | 3270      | 3992      | 5218      | 5560      | 4722      | 3617      | 2327      | 1295      | 818       | 592       | 382       |
| 1999 | 2   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0         | 1         | 5         | 31        | 31        | 32        | 30        | 21        | 9         | 15        | 12        | 15        | 10        | 5         | 6         | 5         |
| 1999 | 3   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 2        | 1        | 0         | 2         | 18        | 51        | 114       | 164       | 145       | 144       | 121       | 96        | 88        | 82        | 53        | 36        | 14        | 5         |
| 2000 | 1   | 0          | 0        | 0        | 2        | 2        | 7        | 63       | 187      | 173      | 236       | 559       | 1075      | 3035      | 4364      | 4870      | 4763      | 4839      | 5349      | 4673      | 3869      | 3230      | 2655      | 1546      | 952       | 636       |
| 2000 | 2   | 0          | 0        | 0        | 0        | 0        | 0        | 1        | 4        | 2        | 4         | 13        | 18        | 41        | 76        | 67        | 34        | 22        | 8         | 5         | 6         | 2         | 1         | 0         | 0         | 0         |
| 2000 | 3   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0         | 0         | 0         | 3         | 13        | 20        | 12        | 8         | 6         | 3         | 0         | 1         | 1         | 0         | 0         | 0         |
| 2001 | 1   | 0          | 0        | 2        | 1        | 3        | 4        | 22       | 43       | 110      | 173       | 112       | 173       | 920       | 1481      | 2101      | 3334      | 3918      | 3868      | 2698      | 2067      | 1507      | 1114      | 760       | 497       | 252       |

Table 2.9—Length frequencies of Pacific cod in the post-1988 longline fishery by year, period, and length bin.

| Yr.  | Per | Length Bin |          |          |          |          |          |          |          |          |           |           |           |           |           |           |           |           |           |           |           |           |           |           |           |           |
|------|-----|------------|----------|----------|----------|----------|----------|----------|----------|----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
|      |     | <u>1</u>   | <u>2</u> | <u>3</u> | <u>4</u> | <u>5</u> | <u>6</u> | <u>7</u> | <u>8</u> | <u>9</u> | <u>10</u> | <u>11</u> | <u>12</u> | <u>13</u> | <u>14</u> | <u>15</u> | <u>16</u> | <u>17</u> | <u>18</u> | <u>19</u> | <u>20</u> | <u>21</u> | <u>22</u> | <u>23</u> | <u>24</u> | <u>25</u> |
| 1990 | 1   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0         | 4         | 12        | 163       | 784       | 1700      | 2796      | 3536      | 3080      | 2490      | 1599      | 1216      | 728       | 480       | 219       | 93        |
| 1990 | 2   | 0          | 0        | 0        | 0        | 0        | 0        | 6        | 6        | 24       | 56        | 136       | 238       | 794       | 2391      | 5893      | 10108     | 12945     | 12636     | 10237     | 7314      | 5084      | 3262      | 2200      | 889       | 315       |
| 1990 | 3   | 0          | 0        | 0        | 0        | 0        | 0        | 1        | 3        | 1        | 12        | 18        | 56        | 348       | 1644      | 5170      | 9453      | 11864     | 11121     | 8939      | 6057      | 3593      | 2102      | 1291      | 598       | 279       |
| 1991 | 1   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 5        | 14       | 30        | 114       | 306       | 1052      | 2487      | 5075      | 8929      | 11159     | 9547      | 6917      | 4040      | 2444      | 1331      | 780       | 311       | 130       |
| 1991 | 2   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 5        | 9        | 19        | 35        | 143       | 773       | 2130      | 4733      | 8310      | 10823     | 12060     | 10930     | 8769      | 6004      | 3203      | 1778      | 793       | 291       |
| 1991 | 3   | 0          | 0        | 0        | 1        | 3        | 18       | 33       | 39       | 62       | 127       | 207       | 467       | 1723      | 4038      | 7030      | 10634     | 13041     | 14086     | 13443     | 10791     | 7589      | 4290      | 2527      | 1104      | 440       |
| 1992 | 1   | 0          | 0        | 0        | 2        | 0        | 3        | 5        | 42       | 90       | 312       | 1253      | 3300      | 10451     | 14863     | 15640     | 19126     | 23004     | 20775     | 15837     | 11594     | 7556      | 4380      | 2455      | 1057      | 407       |
| 1992 | 2   | 0          | 0        | 0        | 0        | 3        | 2        | 3        | 21       | 66       | 174       | 574       | 1325      | 6719      | 13151     | 13754     | 15857     | 17833     | 16704     | 14043     | 11802     | 8990      | 6331      | 4035      | 2045      | 831       |
| 1992 | 3   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 1        | 6        | 19        | 52        | 154       | 765       | 2375      | 2564      | 2390      | 2741      | 2404      | 1939      | 1595      | 1267      | 888       | 565       | 298       | 106       |
| 1993 | 1   | 0          | 0        | 1        | 0        | 1        | 6        | 16       | 76       | 186      | 450       | 1482      | 3328      | 10312     | 20462     | 27089     | 23370     | 17302     | 14383     | 12020     | 9965      | 6845      | 3850      | 1953      | 926       | 314       |
| 1994 | 1   | 0          | 0        | 0        | 3        | 3        | 12       | 23       | 40       | 91       | 223       | 551       | 1472      | 7088      | 17414     | 29142     | 38186     | 32928     | 19177     | 9869      | 6051      | 4280      | 3011      | 1766      | 930       | 325       |
| 1994 | 3   | 0          | 0        | 0        | 0        | 0        | 0        | 2        | 8        | 12       | 57        | 145       | 268       | 952       | 3070      | 5831      | 8261      | 9569      | 7327      | 4226      | 2341      | 1425      | 914       | 505       | 296       | 141       |
| 1995 | 1   | 0          | 0        | 0        | 2        | 5        | 6        | 13       | 24       | 60       | 186       | 1059      | 3031      | 8219      | 14024     | 23789     | 30478     | 28823     | 18233     | 8432      | 3841      | 1961      | 1172      | 730       | 445       | 206       |
| 1995 | 2   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 1         | 0         | 3         | 10        | 33        | 55        | 79        | 56        | 29        | 37        | 38        | 27        | 15        | 9         | 0         | 0         |
| 1995 | 3   | 0          | 0        | 1        | 0        | 0        | 1        | 2        | 21       | 25       | 50        | 219       | 522       | 2929      | 7080      | 8279      | 9857      | 12273     | 11397     | 8717      | 5585      | 3365      | 2040      | 1402      | 714       | 287       |
| 1996 | 1   | 0          | 0        | 0        | 0        | 0        | 0        | 1        | 20       | 73       | 192       | 604       | 1794      | 9116      | 19703     | 26399     | 29777     | 28680     | 21120     | 12783     | 6741      | 3465      | 1691      | 992       | 518       | 382       |
| 1996 | 2   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0         | 0         | 0         | 9         | 27        | 23        | 27        | 17        | 15        | 15        | 14        | 6         | 3         | 0         | 0         | 0         |
| 1996 | 3   | 0          | 0        | 0        | 0        | 0        | 1        | 0        | 4        | 15       | 83        | 182       | 404       | 1626      | 5549      | 11617     | 14477     | 11224     | 8332      | 7296      | 5950      | 4217      | 2391      | 1149      | 562       | 306       |
| 1997 | 1   | 0          | 0        | 0        | 0        | 0        | 1        | 5        | 18       | 92       | 224       | 571       | 1700      | 8606      | 17788     | 30652     | 40069     | 35267     | 21243     | 12004     | 7165      | 4417      | 2557      | 1322      | 651       | 389       |
| 1997 | 2   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0         | 1         | 1         | 4         | 6         | 18        | 18        | 15        | 16        | 5         | 8         | 6         | 4         | 4         | 3         | 0         |
| 1997 | 3   | 0          | 0        | 1        | 2        | 3        | 13       | 20       | 89       | 160      | 288       | 621       | 1673      | 4814      | 9408      | 15198     | 20854     | 26965     | 25031     | 17322     | 8992      | 6074      | 3767      | 1977      | 853       | 364       |
| 1998 | 1   | 0          | 0        | 0        | 0        | 1        | 9        | 19       | 94       | 224      | 414       | 957       | 2524      | 8417      | 13159     | 18857     | 27872     | 30580     | 24229     | 13821     | 7243      | 4858      | 3787      | 2748      | 1747      | 1261      |
| 1998 | 2   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 1         | 1         | 6         | 22        | 4         | 9         | 7         | 4         | 1         | 2         | 3         | 0         | 2         | 0         | 0         | 0         |
| 1998 | 3   | 1          | 0        | 0        | 1        | 32       | 23       | 46       | 45       | 93       | 370       | 1928      | 4087      | 9736      | 15515     | 22466     | 26645     | 30947     | 28225     | 21358     | 13610     | 7212      | 3900      | 2469      | 1211      | 635       |
| 1999 | 1   | 0          | 0        | 0        | 2        | 2        | 0        | 4        | 22       | 60       | 220       | 1263      | 3731      | 8701      | 8787      | 10336     | 12449     | 12238     | 10724     | 7083      | 4170      | 2019      | 1037      | 624       | 408       | 347       |
| 1999 | 2   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 6        | 13        | 44        | 135       | 981       | 1548      | 1315      | 1398      | 1400      | 1230      | 816       | 573       | 328       | 175       | 77        | 42        | 14        |
| 1999 | 3   | 1          | 0        | 0        | 0        | 0        | 1        | 10       | 27       | 61       | 115       | 371       | 707       | 3684      | 7968      | 7048      | 6468      | 6890      | 6175      | 4308      | 3091      | 1886      | 1110      | 554       | 359       | 231       |
| 2000 | 1   | 2          | 0        | 0        | 0        | 0        | 1        | 5        | 16       | 50       | 189       | 679       | 1627      | 6534      | 10526     | 11488     | 9991      | 8549      | 6638      | 4465      | 3133      | 2504      | 1923      | 1339      | 957       | 797       |
| 2000 | 2   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 4         | 10        | 27        | 248       | 654       | 1256      | 1910      | 1616      | 1240      | 891       | 701       | 500       | 397       | 250       | 156       | 100       |
| 2000 | 3   | 1          | 8        | 0        | 0        | 0        | 1        | 3        | 7        | 15       | 71        | 431       | 1300      | 4358      | 10130     | 16501     | 21226     | 16982     | 10164     | 6387      | 4077      | 2569      | 1573      | 881       | 569       | 443       |
| 2001 | 1   | 1          | 0        | 0        | 0        | 2        | 2        | 5        | 27       | 117      | 363       | 581       | 1283      | 5348      | 10261     | 14343     | 16444     | 13790     | 8609      | 4961      | 2958      | 1878      | 1393      | 955       | 705       | 552       |

Table 2.10—Length frequencies of Pacific cod in the pot fishery by year, period, and length bin.

| Yr.  | Per | Length Bin |          |          |          |          |          |          |          |          |           |           |           |           |           |           |           |           |           |           |           |           |           |           |           |           |
|------|-----|------------|----------|----------|----------|----------|----------|----------|----------|----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
|      |     | <u>1</u>   | <u>2</u> | <u>3</u> | <u>4</u> | <u>5</u> | <u>6</u> | <u>7</u> | <u>8</u> | <u>9</u> | <u>10</u> | <u>11</u> | <u>12</u> | <u>13</u> | <u>14</u> | <u>15</u> | <u>16</u> | <u>17</u> | <u>18</u> | <u>19</u> | <u>20</u> | <u>21</u> | <u>22</u> | <u>23</u> | <u>24</u> | <u>25</u> |
| 1990 | 2   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0         | 0         | 1         | 7         | 42        | 74        | 141       | 230       | 293       | 220       | 229       | 138       | 81        | 45        | 3         | 2         |
| 1990 | 3   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0         | 0         | 1         | 3         | 10        | 116       | 512       | 1149      | 1146      | 1360      | 701       | 391       | 260       | 109       | 11        | 3         |
| 1991 | 2   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0         | 0         | 0         | 39        | 240       | 572       | 1106      | 1700      | 2050      | 1874      | 1636      | 875       | 414       | 155       | 35        | 5         |
| 1991 | 3   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0         | 0         | 6         | 29        | 163       | 406       | 790       | 1444      | 2084      | 2236      | 1810      | 1218      | 637       | 290       | 101       | 29        |
| 1992 | 1   | 0          | 0        | 0        | 0        | 0        | 1        | 0        | 1        | 0        | 8         | 7         | 24        | 174       | 380       | 731       | 1875      | 3807      | 3583      | 2710      | 1776      | 1160      | 590       | 324       | 99        | 39        |
| 1992 | 2   | 0          | 0        | 0        | 0        | 0        | 0        | 1        | 2        | 5        | 36        | 103       | 438       | 2186      | 3592      | 4075      | 5205      | 6914      | 7708      | 7212      | 5139      | 3268      | 1601      | 710       | 261       | 113       |
| 1992 | 3   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 2        | 22        | 73        | 145       | 590       | 869       | 749       | 599       | 526       | 406       | 327       | 306       | 200       | 151       | 79        | 48        | 55        |
| 1993 | 1   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0         | 8         | 28        | 320       | 824       | 1448      | 1968      | 1869      | 1621      | 1062      | 640       | 384       | 233       | 93        | 41        | 18        |
| 1994 | 1   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 1         | 19        | 125       | 727       | 2791      | 4384      | 4660      | 4567      | 3529      | 2371      | 1284      | 706       | 409       | 238       | 112       | 27        |
| 1994 | 3   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 5        | 3         | 10        | 25        | 152       | 576       | 1095      | 1255      | 1050      | 808       | 601       | 364       | 229       | 136       | 71        | 39        | 17        |
| 1995 | 1   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 1        | 4         | 45        | 242       | 1203      | 3094      | 6944      | 10101     | 9099      | 6435      | 3950      | 2408      | 1608      | 1394      | 826       | 222       | 84        |
| 1995 | 2   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0         | 5         | 56        | 443       | 841       | 1540      | 2499      | 2682      | 2128      | 1816      | 1425      | 1139      | 1007      | 520       | 449       | 236       |
| 1995 | 3   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 1         | 0         | 16        | 275       | 821       | 1444      | 2240      | 2490      | 2142      | 1563      | 1158      | 787       | 449       | 201       | 125       | 29        |
| 1996 | 1   | 0          | 0        | 0        | 0        | 0        | 3        | 5        | 11       | 14       | 39        | 89        | 268       | 2272      | 6731      | 10936     | 13049     | 13395     | 10997     | 7115      | 4724      | 2883      | 1910      | 1123      | 588       | 241       |
| 1996 | 2   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 1        | 1         | 6         | 43        | 389       | 1293      | 2879      | 3807      | 3552      | 2788      | 2147      | 1939      | 1517      | 1126      | 771       | 513       | 291       |
| 1996 | 3   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0         | 3         | 12        | 174       | 464       | 953       | 1766      | 1923      | 1526      | 1088      | 991       | 929       | 668       | 400       | 218       | 84        |
| 1997 | 1   | 0          | 0        | 0        | 0        | 1        | 0        | 0        | 1        | 3        | 15        | 38        | 82        | 647       | 2100      | 5113      | 9620      | 10616     | 6855      | 3690      | 1963      | 1239      | 838       | 530       | 311       | 197       |
| 1997 | 2   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 1        | 0        | 1         | 7         | 22        | 164       | 454       | 973       | 1685      | 2434      | 2523      | 1440      | 704       | 477       | 393       | 270       | 143       | 69        |
| 1997 | 3   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 1        | 0        | 1         | 7         | 22        | 164       | 454       | 973       | 1685      | 2434      | 2523      | 1440      | 704       | 477       | 393       | 270       | 143       | 69        |
| 1998 | 1   | 0          | 0        | 0        | 0        | 1        | 0        | 0        | 0        | 2        | 4         | 17        | 93        | 695       | 1363      | 2166      | 4743      | 6257      | 5386      | 3157      | 1369      | 579       | 372       | 213       | 118       | 60        |
| 1998 | 2   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 5         | 12        | 159       | 524       | 934       | 1372      | 1824      | 1709      | 1051      | 520       | 280       | 210       | 131       | 111       | 57        |           |
| 1998 | 3   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 1        | 0        | 3         | 8         | 10        | 70        | 257       | 405       | 605       | 730       | 788       | 587       | 396       | 247       | 147       | 130       | 72        | 66        |
| 1999 | 1   | 0          | 0        | 0        | 0        | 0        | 0        | 1        | 2        | 2        | 6         | 17        | 106       | 918       | 1497      | 2389      | 3677      | 3882      | 3557      | 2484      | 1586      | 958       | 656       | 392       | 332       | 172       |
| 1999 | 2   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0         | 2         | 7         | 58        | 123       | 151       | 239       | 239       | 257       | 198       | 170       | 148       | 116       | 72        | 51        | 44        |
| 1999 | 3   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 4        | 12        | 21        | 53        | 305       | 793       | 1153      | 1122      | 1255      | 1086      | 835       | 696       | 585       | 442       | 249       | 202       | 109       |
| 2000 | 1   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 1        | 2        | 2         | 12        | 112       | 934       | 2545      | 4019      | 4085      | 3753      | 3482      | 2412      | 1715      | 1125      | 882       | 487       | 256       | 216       |
| 2000 | 3   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 1         | 1         | 3         | 39        | 87        | 134       | 149       | 62        | 25        | 8         | 0         | 2         | 1         | 0         | 0         | 0         |
| 2001 | 1   | 4          | 0        | 1        | 0        | 0        | 0        | 0        | 0        | 0        | 0         | 3         | 13        | 225       | 766       | 2097      | 3736      | 3734      | 2103      | 958       | 407       | 251       | 154       | 100       | 45        | 80        |
| 2001 | 2   | 0          | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0         | 0         | 0         | 0         | 2         | 25        | 50        | 46        | 50        | 33        | 23        | 4         | 3         | 1         | 1         | 1         |

Table 2.11–Length frequencies of Pacific cod in the trawl survey by year (all surveys take place in period 2). Numbers shown are survey estimates of population numbers at length, rescaled so that the sum equals the total size of the actual survey length sample.

| Yr.  | Per | Length Bin |          |          |          |          |          |          |          |          |           |           |           |           |           |           |           |           |           |           |           |           |           |           |           |           |
|------|-----|------------|----------|----------|----------|----------|----------|----------|----------|----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
|      |     | <u>1</u>   | <u>2</u> | <u>3</u> | <u>4</u> | <u>5</u> | <u>6</u> | <u>7</u> | <u>8</u> | <u>9</u> | <u>10</u> | <u>11</u> | <u>12</u> | <u>13</u> | <u>14</u> | <u>15</u> | <u>16</u> | <u>17</u> | <u>18</u> | <u>19</u> | <u>20</u> | <u>21</u> | <u>22</u> | <u>23</u> | <u>24</u> | <u>25</u> |
| 1979 | 2   | 0          | 5        | 44       | 186      | 374      | 457      | 694      | 1764     | 2393     | 1884      | 1171      | 618       | 202       | 70        | 44        | 51        | 29        | 8         | 0         | 3         | 1         | 1         | 0         | 0         | 0         |
| 1980 | 2   | 0          | 6        | 85       | 241      | 82       | 42       | 224      | 687      | 929      | 1320      | 1542      | 2062      | 1364      | 893       | 333       | 100       | 33        | 31        | 19        | 6         | 2         | 0         | 0         | 0         | 0         |
| 1981 | 2   | 0          | 20       | 156      | 330      | 278      | 32       | 100      | 330      | 653      | 724       | 511       | 1063      | 1396      | 1746      | 1215      | 812       | 398       | 156       | 39        | 27        | 13        | 1         | 0         | 0         | 0         |
| 1982 | 2   | 16         | 84       | 205      | 132      | 35       | 27       | 124      | 384      | 732      | 718       | 391       | 769       | 1179      | 1256      | 1232      | 1135      | 821       | 450       | 192       | 80        | 26        | 8         | 3         | 0         | 0         |
| 1983 | 2   | 278        | 996      | 939      | 460      | 109      | 23       | 100      | 264      | 405      | 294       | 163       | 483       | 891       | 1024      | 1069      | 891       | 700       | 514       | 247       | 111       | 22        | 14        | 3         | 1         | 0         |
| 1984 | 2   | 43         | 88       | 66       | 120      | 252      | 762      | 1380     | 1426     | 858      | 389       | 200       | 291       | 361       | 481       | 708       | 783       | 713       | 478       | 320       | 152       | 83        | 36        | 10        | 1         | 0         |
| 1985 | 2   | 88         | 325      | 573      | 893      | 1004     | 387      | 179      | 362      | 544      | 580       | 703       | 1194      | 815       | 392       | 282       | 322       | 408       | 401       | 294       | 148       | 69        | 24        | 10        | 4         | 0         |
| 1986 | 2   | 91         | 286      | 320      | 99       | 75       | 452      | 1163     | 1257     | 1040     | 711       | 359       | 396       | 573       | 869       | 776       | 406       | 268       | 296       | 244       | 171       | 79        | 48        | 13        | 8         | 0         |
| 1987 | 2   | 18         | 72       | 248      | 385      | 258      | 179      | 413      | 847      | 729      | 580       | 600       | 1231      | 1089      | 768       | 551       | 604       | 581       | 378       | 193       | 151       | 61        | 45        | 15        | 6         | 0         |
| 1988 | 2   | 9          | 53       | 80       | 91       | 109      | 236      | 282      | 393      | 666      | 627       | 493       | 987       | 1102      | 1310      | 1086      | 833       | 559       | 414       | 293       | 234       | 75        | 33        | 28        | 7         | 0         |
| 1989 | 2   | 17         | 137      | 316      | 224      | 69       | 37       | 92       | 102      | 147      | 350       | 347       | 565       | 709       | 1218      | 1308      | 1138      | 941       | 800       | 632       | 326       | 234       | 146       | 87        | 59        | 0         |
| 1990 | 2   | 203        | 491      | 689      | 357      | 132      | 124      | 263      | 303      | 323      | 277       | 174       | 160       | 169       | 224       | 349       | 408       | 276       | 262       | 170       | 123       | 82        | 33        | 25        | 10        | 1         |
| 1991 | 2   | 141        | 408      | 447      | 381      | 228      | 262      | 595      | 867      | 912      | 611       | 349       | 249       | 259       | 327       | 260       | 226       | 211       | 181       | 108       | 107       | 49        | 20        | 22        | 7         | 1         |
| 1992 | 2   | 18         | 468      | 451      | 565      | 514      | 455      | 891      | 1092     | 872      | 560       | 462       | 889       | 699       | 564       | 244       | 233       | 186       | 108       | 101       | 91        | 54        | 38        | 30        | 15        | 1         |
| 1993 | 2   | 114        | 924      | 1087     | 981      | 677      | 213      | 247      | 614      | 847      | 666       | 489       | 845       | 842       | 665       | 398       | 267       | 230       | 85        | 62        | 49        | 36        | 21        | 24        | 15        | 6         |
| 1994 | 2   | 18         | 145      | 291      | 361      | 327      | 446      | 957      | 1924     | 2082     | 1121      | 443       | 685       | 1051      | 964       | 1058      | 920       | 565       | 288       | 92        | 46        | 33        | 60        | 15        | 22        | 8         |
| 1995 | 2   | 29         | 74       | 135      | 208      | 77       | 172      | 460      | 691      | 580      | 705       | 1064      | 1575      | 1017      | 617       | 434       | 484       | 326       | 253       | 133       | 84        | 41        | 27        | 18        | 9         | 3         |
| 1996 | 2   | 14         | 65       | 164      | 198      | 110      | 103      | 357      | 699      | 677      | 526       | 499       | 744       | 1477      | 1404      | 908       | 499       | 288       | 237       | 148       | 109       | 71        | 25        | 16        | 7         | 3         |
| 1997 | 2   | 91         | 472      | 601      | 728      | 507      | 140      | 215      | 481      | 628      | 451       | 407       | 399       | 918       | 809       | 842       | 583       | 436       | 215       | 105       | 60        | 40        | 26        | 10        | 4         | 1         |
| 1998 | 2   | 30         | 262      | 334      | 74       | 46       | 311      | 1151     | 1837     | 1396     | 655       | 379       | 367       | 659       | 458       | 378       | 391       | 333       | 244       | 132       | 64        | 33        | 29        | 9         | 10        | 1         |
| 1999 | 2   | 71         | 335      | 286      | 113      | 141      | 415      | 760      | 874      | 667      | 719       | 1169      | 1648      | 1854      | 768       | 493       | 447       | 337       | 252       | 130       | 89        | 62        | 37        | 24        | 7         | 2         |
| 2000 | 2   | 175        | 918      | 1310     | 505      | 54       | 141      | 488      | 785      | 604      | 564       | 749       | 958       | 1720      | 1419      | 894       | 537       | 266       | 188       | 99        | 79        | 57        | 33        | 19        | 3         | 0         |
| 2001 | 2   | 95         | 640      | 1815     | 2110     | 1011     | 407      | 903      | 1994     | 2550     | 1618      | 706       | 486       | 1193      | 1278      | 1080      | 819       | 515       | 257       | 123       | 71        | 34        | 22        | 14        | 4         | 5         |

Table 2.12--Biomass, standard error, 95% confidence interval (CI), and population numbers of Pacific cod estimated by NMFS' annual bottom trawl survey of the EBS shelf. All figures except population numbers are expressed in metric tons. Population numbers are expressed in terms of individual fish.

| Year  | Biomass   | Standard Error | Lower 95% CI | Upper 95% CI | Numbers       |
|-------|-----------|----------------|--------------|--------------|---------------|
| 1979  | 754,314   | 97,844         | 562,539      | 946,089      | 1,530,429,650 |
| 1980  | 905,344   | 87,898         | 733,063      | 1,077,624    | 1,084,147,540 |
| 1981  | 1,034,629 | 123,849        | 791,885      | 1,277,373    | 794,619,624   |
| 1982  | 1,020,550 | 73,392         | 876,701      | 1,164,399    | 583,715,089   |
| 1983  | 1,176,305 | 121,606        | 937,958      | 1,414,651    | 725,351,369   |
| 1984  | 1,001,940 | 64,127         | 876,251      | 1,127,629    | 636,948,300   |
| 1985  | 961,050   | 51,453         | 860,203      | 1,061,896    | 800,070,473   |
| 1986  | 1,134,106 | 71,813         | 993,353      | 1,274,858    | 843,460,794   |
| 1987  | 1,142,450 | 71,439         | 1,002,430    | 1,282,468    | 754,269,021   |
| 1988  | 959,544   | 76,284         | 810,028      | 1,109,060    | 509,336,483   |
| 1989  | 960,436   | 69,157         | 824,888      | 1,095,984    | 339,719,445   |
| 1990  | 708,551   | 53,728         | 603,245      | 813,857      | 435,856,535   |
| 1991  | 532,590   | 41,678         | 450,902      | 614,279      | 496,841,261   |
| 1992* | 546,707   | 45,754         | 457,030      | 636,383      | 577,416,832   |
| 1993  | 690,524   | 54,934         | 582,853      | 798,196      | 851,866,426   |
| 1994  | 1,368,109 | 254,435        | 869,416      | 1,866,802    | 1,237,760,162 |
| 1995  | 1,003,046 | 92,677         | 821,400      | 1,184,692    | 757,576,445   |
| 1996  | 890,793   | 120,522        | 652,160      | 1,129,426    | 609,304,214   |
| 1997  | 604,881   | 69,250         | 466,382      | 743,380      | 487,429,700   |
| 1998  | 534,141   | 42,942         | 449,116      | 619,166      | 514,321,475   |
| 1999  | 583,259   | 50,622         | 483,028      | 683,490      | 500,692,872   |
| 2000  | 528,466   | 43,037         | 443,253      | 613,679      | 481,358,109   |
| 2001  | 830,479   | 75,675         | 679,130      | 981,829      | 980,493,794   |

\*During the 1992 field season, 18 stations were omitted from the standard survey grid due to severe weather and vessel problems. In 1989, 1990, and 1991, these 18 stations represented, on average, 2.2% and 2.8% of the total Pacific cod biomass and numbers, respectively. The 1992 point estimates and confidence interval shown above have been adjusted upward proportionately.

Table 2.13—Magnitude of hydroacoustic, longline, and bottom trawl survey removals (t) in the EBS and AI from 1977 through 2001. Cells with an entry of zero indicate that survey removals amounted to less than 0.5 t, whereas cells with no entry indicate that there was no survey in that region and year. Longline survey removals for 1998-2001 reported under “Eastern Bering Sea” are for the EBS and AI combined.

| Year | Eastern Bering Sea |                 |              |              | Aleutians       |                 |              |              |
|------|--------------------|-----------------|--------------|--------------|-----------------|-----------------|--------------|--------------|
|      | <u>Acoustic</u>    | <u>Longline</u> | <u>Trawl</u> | <u>Total</u> | <u>Acoustic</u> | <u>Longline</u> | <u>Trawl</u> | <u>Total</u> |
| 1977 |                    |                 | 4            | 4            |                 |                 |              |              |
| 1978 | 1                  |                 | 25           | 26           |                 |                 |              |              |
| 1979 | 0                  | 4               | 61           | 65           |                 | 10              |              | 10           |
| 1980 |                    | 5               | 37           | 42           |                 | 16              | 64           | 80           |
| 1981 |                    | 8               | 94           | 102          |                 | 23              |              | 23           |
| 1982 | 1                  | 82              | 115          | 198          |                 | 42              | 153          | 195          |
| 1983 |                    | 79              | 95           | 174          |                 | 36              | 102          | 138          |
| 1984 |                    | 94              | 52           | 145          |                 | 42              |              | 42           |
| 1985 | 0                  | 111             | 100          | 211          |                 | 58              |              | 58           |
| 1986 |                    | 121             | 41           | 162          |                 | 58              | 98           | 155          |
| 1987 |                    | 126             | 41           | 167          |                 | 58              |              | 58           |
| 1988 | 0                  | 102             | 71           | 173          |                 | 54              |              | 54           |
| 1989 | 1                  | 160             | 56           | 217          |                 | 43              |              | 43           |
| 1990 | 1                  | 133             | 50           | 184          |                 | 56              |              | 56           |
| 1991 | 2                  | 101             | 74           | 177          |                 | 72              | 37           | 109          |
| 1992 | 0                  | 57              | 17           | 74           |                 | 81              |              | 81           |
| 1993 | 0                  | 76              | 25           | 101          |                 | 56              |              | 56           |
| 1994 | 2                  | 98              | 49           | 149          |                 | 60              | 62           | 122          |
| 1995 | 2                  | 0               | 52           | 54           |                 | 0               |              | 0            |
| 1996 | 0                  | 0               | 32           | 33           |                 | 11              |              | 11           |
| 1997 | 0                  | 24              | 26           | 50           |                 | 0               | 20           | 20           |
| 1998 | 0                  | 18              | 21           | 39           |                 | n/a             |              |              |
| 1999 | 1                  | 19              | 26           | 46           |                 | n/a             |              |              |
| 2000 | 1                  | 15              | 20           | 36           |                 | n/a             | 24           | 24           |
| 2001 | 0                  | 22              | 34           | 56           |                 | n/a             |              |              |

Table 2.14—Symbols used in the Synthesis assessment model for Pacific cod (page 1 of 2).

### Indices

|     |               |
|-----|---------------|
| $a$ | age group     |
| $g$ | gear type     |
| $i$ | time interval |
| $j$ | size bin      |
| $y$ | year          |

### Dimensions

|           |                                       |
|-----------|---------------------------------------|
| $a_{min}$ | age of youngest group                 |
| $a_{max}$ | age of oldest group                   |
| $g_{max}$ | number of gear types                  |
| $i_{max}$ | number of time intervals in each year |
| $j_{max}$ | number of size bins                   |
| $y_{max}$ | number of years                       |

### Special Values of Indices

|           |  |
|-----------|--|
| $a_{rec}$ | index of age group used to assess recruitment strength |
| $g_{sur}$ | index of survey gear type                              |
| $i_{spa}$ | index of time interval during which spawning occurs    |
| $i_{sur}$ | index of time interval during which survey occurs      |

### Operators

|           |   |
|-----------|---|
| $e(y g)$  | returns the era containing year $y$ given gear type $g$     |
| $l_{mid}$ | returns the length corresponding to the midpoint of bin $j$ |
| $l_{min}$ | returns the smallest length contained in bin $j$            |
| $t_{dur}$ | returns the duration (in years) of time interval $i$        |

### Continuous Variables

|           |        |
|-----------|--------|
| $\alpha$  | age    |
| $\lambda$ | length |
| $\tau$    | time   |

### Special Values of Continuous Variables

|                 |  |
|-----------------|--|
| $\alpha_1$      | first reference age used in length-at-age relationship (in years)  |
| $\alpha_2$      | second reference age used in length-at-age relationship (in years) |
| $\lambda_{min}$ | minimum length used in assessment                                  |
| $\lambda_{max}$ | maximum length used in assessment                                  |
| $\tau_{spa}$    | annual time of spawning (in years)                                 |
| $\tau_{sur}$    | annual time of survey (in years)                                   |

Table 2.14—Symbols used in the Synthesis assessment model for Pacific cod (page 2 of 2).

Functions of Age or Length

|                     |   |
|---------------------|---|
| $h(\lambda \alpha)$ | probability density function describing distribution of length, conditional on age      |
| $l(\alpha)$         | length at age   |
| $p(\lambda)$        | proportion mature at length   |
| $s(\lambda g,y)$    | selectivity at length, conditional on gear type and year                                |
| $w(\lambda)$        | weight at length  |
| $x(\alpha)$         | standard deviation associated with the length-at-age relationship, as a function of age |

Arrays Generated by Synthesis

|             |  |
|-------------|--|
| $b_y$       | biomass of population aged $a \geq a_{rec}$ at start of year $y$                               |
| $c_y$       | spawning biomass at time of spawning in year $y$   |
| $d_y$       | survey biomass at time of survey in year $y$   |
| $n_{a,y,i}$ | population numbers at age $a$ , year $y$ , and time interval $i$                               |
| $u_{a,y}$   | population numbers at time of spawning at age $a$ and year $y$                                 |
| $v_{a,y}$   | population numbers at time of survey at age $a$ and year $y$                                   |
| $z_{a,i,j}$ | proportion of length distribution falling within size bin $j$ at age $a$ and time interval $i$ |

Parameters Used by Synthesis

|                  |  |
|------------------|--|
| $F_{g,y,i}$      | instantaneous fishing mortality rate at each gear $g$ , year $y$ , and time $i$ for which catch>0    |
| $K$              | Brody's growth parameter   |
| $L_1$            | length at age $\alpha_1$   |
| $L_2$            | length at age $\alpha_2$   |
| $M$              | instantaneous natural mortality rate   |
| $N_a$            | initial population numbers at each age $a > a_{min}$   |
| $P_1$            | length at point of inflection in maturity schedule   |
| $P_2$            | relative slope at point of inflection in maturity schedule   |
| $Q$              | survey catchability  |
| $R_y$            | recruitment at age $a_{min}$ in year $y$   |
| $S_{1,g,e(y g)}$ | selectivity at minimum length in gear type $g$ and era $e$   |
| $S_{2,g,e(y g)}$ | length at inflection in ascending part of selectivity schedule in gear type $g$ and era $e$          |
| $S_{3,g,e(y g)}$ | relative slope at inflection in ascending part of selectivity schedule in gear type $g$ and era $e$  |
| $S_{4,g,e(y g)}$ | length at maximum selectivity in gear type $g$ and era $e$   |
| $S_{5,g,e(y g)}$ | selectivity at maximum length in gear type $g$ and era $e$   |
| $S_{6,g,e(y g)}$ | length at inflection in descending part of selectivity schedule in gear type $g$ and era $e$         |
| $S_{7,g,e(y g)}$ | relative slope at inflection in descending part of selectivity schedule in gear type $g$ and era $e$ |
| $W_1$            | weight-length proportionality  |
| $W_2$            | weight-length exponent   |
| $X_1$            | standard deviation of length evaluated at age $\alpha_1$   |
| $X_2$            | standard deviation of length evaluated at age $\alpha_2$   |

Table 2.15—Dimensions and special values of indices and variables used in the Pacific cod assessment. Symbols are defined in Table 2.14.

#### Dimensions

| <u>Term</u> | <u>Value</u> | <u>Comments/Rationale</u>   |
|-------------|--------------|---|
| $a_{min}$   | 1            | assumed minimum age group observed in the trawl survey                    |
| $a_{max}$   | 12           | a convenient place to insert an “age-plus” category                       |
| $g_{max}$   | 6            | early trawl, late trawl, longline, pot, pre-1982 survey, post-1981 survey |
| $i_{max}$   | 3            | January through March, June through August, September through December    |
| $j_{max}$   | 25           | bin boundaries are given in the “Data” section of the text                |
| $y_{max}$   | 24           | 1978 through 2001   |

#### Special Values of Indices

| <u>Term</u> | <u>Value</u> | <u>Comments/Rationale</u>   |
|-------------|--------------|---|
| $a_{rec}$   | 3            | age traditionally used to indicate first significant recruitment to the fishery |
| $g_{sur}$   | 6            | index of post-1981 survey gear type   |
| $i_{spa}$   | 1            | March (see $\tau_{spa}$ below) falls within the first intra-annual time period  |
| $i_{sur}$   | 2            | July (see $\tau_{sur}$ below) falls within the second intra-annual time period  |

#### Special Values of Continuous Variables

| <u>Term</u>     | <u>Value</u> | <u>Comments/Rationale</u>   |
|-----------------|--------------|---|
| $\alpha_1$      | 1.5          | assumed age of youngest fish seen in the trawl survey                         |
| $\alpha_2$      | 12.0         | set equal to the lower bound of the age-plus group for convenience            |
| $\lambda_{min}$ | 9            | close to the length of the smallest fish seen by the survey in a typical year |
| $\lambda_{max}$ | 115          | close to the length of the largest fish seen by the survey in a typical year  |
| $\tau_{spa}$    | (3-1)/12     | March appears to be the month of peak spawning in the observer data           |
| $\tau_{sur}$    | (7-1)/12     | July is the approximate mid-point of the June-August trawl survey season      |

Table 2.16—Partitioning the list of parameters used in the Synthesis model of Pacific cod into those that are estimated independently (i.e., outside) of Synthesis and those that are estimated conditionally (i.e., inside of Synthesis).

Parameters Estimated Independently

---

|       |  |
|-------|--|
| $L_1$ | length at age $\alpha_1$                                   |
| $M$   | instantaneous natural mortality rate                       |
| $P_1$ | length at point of inflection in maturity schedule         |
| $P_2$ | relative slope at point of inflection in maturity schedule |
| $Q$   | survey catchability  |
| $W_1$ | weight-length proportionality                              |
| $W_2$ | weight-length exponent                                     |
| $X_1$ | standard deviation of length evaluated at age $\alpha_1$   |
| $X_2$ | standard deviation of length evaluated at age $\alpha_2$   |

Parameters Estimated Conditionally

---

|                  |  |
|------------------|--|
| $F_{g,y,i}$      | instantaneous fishing mortality rate at each gear $g$ , year $y$ , and time $i$ for which catch>0    |
| $K$              | Brody's growth parameter   |
| $L_2$            | length at age $\alpha_2$   |
| $N_a$            | initial population numbers at each age $a > a_{min}$   |
| $R_y$            | recruitment at age $a_{min}$ in year $y$   |
| $S_{1,g,e(y g)}$ | selectivity at minimum length in gear type $g$ and era $e$   |
| $S_{2,g,e(y g)}$ | length at inflection in ascending part of selectivity schedule in gear type $g$ and era $e$          |
| $S_{3,g,e(y g)}$ | relative slope at inflection in ascending part of selectivity schedule in gear type $g$ and era $e$  |
| $S_{4,g,e(y g)}$ | length at maximum selectivity in gear type $g$ and era $e$   |
| $S_{5,g,e(y g)}$ | selectivity at maximum length in gear type $g$ and era $e$   |
| $S_{6,g,e(y g)}$ | length at inflection in descending part of selectivity schedule in gear type $g$ and era $e$         |
| $S_{7,g,e(y g)}$ | relative slope at inflection in descending part of selectivity schedule in gear type $g$ and era $e$ |

Table 2.17–Pacific cod commercial fishery length sample sizes used in the multinomial distribution. (These values correspond to the square roots of the true sample sizes shown in Table 2.5.)

| Year | Trawl Fishery |               |               | Longline Fishery |               |               | Pot Fishery   |               |               |
|------|---------------|---------------|---------------|------------------|---------------|---------------|---------------|---------------|---------------|
|      | <u>Per. 1</u> | <u>Per. 2</u> | <u>Per. 3</u> | <u>Per. 1</u>    | <u>Per. 2</u> | <u>Per. 3</u> | <u>Per. 1</u> | <u>Per. 2</u> | <u>Per. 3</u> |
| 1978 | 25            | 0             | 56            | 54               | 70            | 50            | 0             | 0             | 0             |
| 1979 | 41            | 0             | 27            | 107              | 50            | 52            | 0             | 0             | 0             |
| 1980 | 37            | 9             | 18            | 51               | 37            | 54            | 0             | 0             | 0             |
| 1981 | 11            | 0             | 39            | 47               | 36            | 36            | 0             | 0             | 0             |
| 1982 | 24            | 15            | 41            | 54               | 35            | 71            | 0             | 0             | 0             |
| 1983 | 111           | 35            | 121           | 137              | 64            | 98            | 0             | 0             | 0             |
| 1984 | 101           | 67            | 67            | 83               | 77            | 287           | 0             | 0             | 0             |
| 1985 | 174           | 39            | 55            | 0                | 68            | 367           | 0             | 0             | 0             |
| 1986 | 169           | 43            | 50            | 136              | 14            | 323           | 0             | 0             | 0             |
| 1987 | 215           | 82            | 145           | 265              | 0             | 406           | 0             | 0             | 0             |
| 1988 | 322           | 0             | 54            | 0                | 0             | 0             | 0             | 0             | 0             |
| 1989 | 242           | 25            | 26            | 0                | 0             | 0             | 0             | 0             | 0             |
| 1990 | 253           | 99            | 16            | 137              | 273           | 250           | 0             | 39            | 76            |
| 1991 | 298           | 46            | 0             | 234              | 266           | 303           | 0             | 103           | 106           |
| 1992 | 282           | 0             | 0             | 390              | 366           | 142           | 131           | 220           | 72            |
| 1993 | 286           | 0             | 0             | 393              | 0             | 0             | 103           | 0             | 0             |
| 1994 | 322           | 0             | 0             | 415              | 0             | 213           | 161           | 0             | 80            |
| 1995 | 262           | 0             | 0             | 380              | 20            | 273           | 218           | 130           | 117           |
| 1996 | 323           | 34            | 59            | 405              | 12            | 275           | 276           | 152           | 106           |
| 1997 | 327           | 17            | 0             | 430              | 10            | 380           | 209           | 108           | 108           |
| 1998 | 329           | 53            | 55            | 404              | 8             | 437           | 163           | 94            | 67            |
| 1999 | 212           | 15            | 34            | 290              | 100           | 226           | 150           | 43            | 94            |
| 2000 | 217           | 17            | 8             | 267              | 100           | 313           | 161           | 0             | 23            |
| 2001 | 159           | 40            | n/a           | 291              | 84            | n/a           | 121           | 15            | n/a           |

Table 2.18—Estimates of Pacific cod fishing mortality rates, expressed on an annual time scale. Empty cells indicate that no catch was recorded.

| Year | Trawl         |               |               | Longline      |               |               | Pot           |               |               |
|------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|
|      | <u>Per. 1</u> | <u>Per. 2</u> | <u>Per. 3</u> | <u>Per. 1</u> | <u>Per. 2</u> | <u>Per. 3</u> | <u>Per. 1</u> | <u>Per. 2</u> | <u>Per. 3</u> |
| 1978 | 0.11          | 0.23          | 0.25          | 0.02          | 0.02          | 0.03          |               |               |               |
| 1979 | 0.07          | 0.16          | 0.09          | 0.01          | 0.01          | 0.00          |               |               |               |
| 1980 | 0.04          | 0.06          | 0.08          | 0.01          | 0.00          | 0.02          |               |               |               |
| 1981 | 0.03          | 0.05          | 0.06          | 0.00          | 0.00          | 0.01          |               |               |               |
| 1982 | 0.03          | 0.05          | 0.03          | 0.00          | 0.00          | 0.00          |               |               |               |
| 1983 | 0.05          | 0.05          | 0.04          | 0.00          | 0.00          | 0.00          |               |               |               |
| 1984 | 0.06          | 0.05          | 0.04          | 0.01          | 0.00          | 0.03          |               |               |               |
| 1985 | 0.07          | 0.06          | 0.04          | 0.02          | 0.00          | 0.04          |               |               |               |
| 1986 | 0.08          | 0.06          | 0.04          | 0.01          | 0.00          | 0.03          |               |               |               |
| 1987 | 0.08          | 0.03          | 0.04          | 0.03          | 0.00          | 0.05          |               |               |               |
| 1988 | 0.16          | 0.06          | 0.08          | 0.00          | 0.00          | 0.00          | 0.00          | 0.00          | 0.00          |
| 1989 | 0.16          | 0.03          | 0.03          | 0.01          | 0.01          | 0.01          | 0.00          | 0.00          | 0.00          |
| 1990 | 0.14          | 0.02          | 0.02          | 0.02          | 0.05          | 0.04          |               | 0.00          | 0.00          |
| 1991 | 0.17          | 0.04          | 0.01          | 0.05          | 0.08          | 0.08          | 0.00          | 0.00          | 0.01          |
| 1992 | 0.11          | 0.03          | 0.01          | 0.12          | 0.10          | 0.02          | 0.01          | 0.02          | 0.00          |
| 1993 | 0.13          | 0.02          | 0.02          | 0.12          | 0.00          | 0.00          | 0.01          | 0.00          |               |
| 1994 | 0.12          | 0.02          | 0.04          | 0.13          | 0.00          | 0.06          | 0.01          |               | 0.01          |
| 1995 | 0.18          | 0.03          | 0.03          | 0.16          | 0.00          | 0.08          | 0.03          | 0.01          | 0.01          |
| 1996 | 0.16          | 0.01          | 0.02          | 0.14          | 0.00          | 0.08          | 0.04          | 0.03          | 0.01          |
| 1997 | 0.17          | 0.01          | 0.02          | 0.17          | 0.00          | 0.15          | 0.04          | 0.02          | 0.01          |
| 1998 | 0.10          | 0.02          | 0.03          | 0.15          | 0.00          | 0.12          | 0.02          | 0.01          | 0.01          |
| 1999 | 0.11          | 0.01          | 0.01          | 0.17          | 0.01          | 0.09          | 0.03          | 0.01          | 0.01          |
| 2000 | 0.11          | 0.02          | 0.01          | 0.12          | 0.01          | 0.15          | 0.05          |               | 0.00          |
| 2001 | 0.06          | 0.03          | 0.02          | 0.11          | 0.03          | 0.12          | 0.04          | 0.00          | 0.00          |

Table 2.19—Estimates of Pacific cod recruitment at age 1 and initial numbers at age (in millions of fish).

| <u>Year</u> | <u>Recruitment at age 1</u> |
|-------------|-----------------------------|
| 1978        | 1465                        |
| 1979        | 654                         |
| 1980        | 742                         |
| 1981        | 590                         |
| 1982        | 190                         |
| 1983        | 1082                        |
| 1984        | 321                         |
| 1985        | 879                         |
| 1986        | 540                         |
| 1987        | 335                         |
| 1988        | 191                         |
| 1989        | 254                         |
| 1990        | 614                         |
| 1991        | 604                         |
| 1992        | 352                         |
| 1993        | 683                         |
| 1994        | 334                         |
| 1995        | 279                         |
| 1996        | 263                         |
| 1997        | 567                         |
| 1998        | 365                         |
| 1999        | 270                         |
| 2000        | 550                         |
| 2001        | 770                         |

| <u>Age</u> | <u>Initial numbers at age</u> |
|------------|-------------------------------|
| 2          | 253                           |
| 3          | 92                            |
| 4          | 103                           |
| 5          | 0                             |
| 6          | 11                            |
| 7          | 3                             |
| 8          | 0                             |
| 9          | 0                             |
| 10         | 0                             |
| 11         | 1                             |
| 12         | 0                             |

Table 2.20—Estimates of Pacific cod selectivity parameters. The first column lists the parameter families for which the remaining columns contain gear- and era- specific estimates. Gear types consist of January-May trawl, June-December trawl, longline, and pot commercial gears, and the trawl survey. Eras consist of the ranges 1978-1988 and 1989-2001 for the commercial gear types, and 1978-1981 and 1982-2001 for the survey gear.

|                  | Trawl (Jan.-May) |                | Trawl (Jun.-Dec.) |                | Longline       |                | Pot            | Survey         |                |
|------------------|------------------|----------------|-------------------|----------------|----------------|----------------|----------------|----------------|----------------|
|                  | <u>1978-88</u>   | <u>1989-01</u> | <u>1978-88</u>    | <u>1989-01</u> | <u>1978-88</u> | <u>1989-01</u> | <u>1989-01</u> | <u>1978-81</u> | <u>1982-01</u> |
| $S_{1,g,e(y g)}$ | 0.00             | 0.00           | 0.00              | 0.00           | 0.00           | 0.00           | 0.00           | 0.00           | 0.13           |
| $S_{2,g,e(y g)}$ | 55.99            | 52.73          | 51.93             | 60.63          | 57.57          | 59.92          | 61.63          | 29.30          | 20.89          |
| $S_{3,g,e(y g)}$ | 0.14             | 0.16           | 0.21              | 0.17           | 0.27           | 0.24           | 0.27           | 0.20           | 0.00           |
| $S_{4,g,e(y g)}$ | 87.97            | 87.23          | 94.01             | 86.17          | 76.84          | 85.11          | 80.13          | 46.52          | 45.46          |
| $S_{5,g,e(y g)}$ | 0.87             | 0.55           | 1.00              | 0.91           | 0.56           | 0.36           | 0.64           | 0.35           | 0.08           |
| $S_{6,g,e(y g)}$ | 88.56            | 93.67          | 94.01             | 86.17          | 83.21          | 85.77          | 80.89          | 47.55          | 46.37          |
| $S_{7,g,e(y g)}$ | 1.16             | 0.34           | 0.10              | 0.92           | 0.24           | 0.12           | 0.25           | 0.13           | 0.05           |

Table 2.21–Distribution of Pacific cod lengths (in cm) at age (mid-year) as defined by final parameter estimates. Lengths correspond to lower bounds of size bins. Columns sum to 1.0.

| Len. | Age Group |          |          |          |          |          |          |          |          |           |           |            |
|------|-----------|----------|----------|----------|----------|----------|----------|----------|----------|-----------|-----------|------------|
|      | <u>1</u>  | <u>2</u> | <u>3</u> | <u>4</u> | <u>5</u> | <u>6</u> | <u>7</u> | <u>8</u> | <u>9</u> | <u>10</u> | <u>11</u> | <u>12+</u> |
| 105  | 0         | 0        | 0        | 0        | 0        | 0        | 0        | 0.001    | 0.005    | 0.017     | 0.040     | 0.154      |
| 100  | 0         | 0        | 0        | 0        | 0        | 0        | 0.001    | 0.006    | 0.026    | 0.062     | 0.105     | 0.173      |
| 95   | 0         | 0        | 0        | 0        | 0        | 0        | 0.006    | 0.036    | 0.095    | 0.161     | 0.213     | 0.222      |
| 90   | 0         | 0        | 0        | 0        | 0        | 0.004    | 0.038    | 0.121    | 0.209    | 0.259     | 0.271     | 0.207      |
| 85   | 0         | 0        | 0        | 0        | 0.001    | 0.027    | 0.129    | 0.241    | 0.280    | 0.260     | 0.218     | 0.141      |
| 80   | 0         | 0        | 0        | 0        | 0.009    | 0.110    | 0.256    | 0.286    | 0.229    | 0.161     | 0.110     | 0.070      |
| 75   | 0         | 0        | 0        | 0.001    | 0.060    | 0.248    | 0.291    | 0.201    | 0.114    | 0.062     | 0.035     | 0.025      |
| 70   | 0         | 0        | 0        | 0.011    | 0.193    | 0.308    | 0.190    | 0.084    | 0.035    | 0.015     | 0.007     | 0.007      |
| 65   | 0         | 0        | 0        | 0.077    | 0.319    | 0.209    | 0.071    | 0.021    | 0.006    | 0.002     | 0.001     | 0.001      |
| 60   | 0         | 0        | 0.004    | 0.241    | 0.271    | 0.078    | 0.015    | 0.003    | 0.001    | 0         | 0         | 0          |
| 55   | 0         | 0        | 0.047    | 0.350    | 0.118    | 0.016    | 0.002    | 0        | 0        | 0         | 0         | 0          |
| 50   | 0         | 0        | 0.211    | 0.236    | 0.026    | 0.002    | 0        | 0        | 0        | 0         | 0         | 0          |
| 45   | 0         | 0.004    | 0.380    | 0.074    | 0.003    | 0        | 0        | 0        | 0        | 0         | 0         | 0          |
| 42   | 0         | 0.021    | 0.190    | 0.009    | 0        | 0        | 0        | 0        | 0        | 0         | 0         | 0          |
| 39   | 0         | 0.077    | 0.108    | 0.002    | 0        | 0        | 0        | 0        | 0        | 0         | 0         | 0          |
| 36   | 0         | 0.180    | 0.043    | 0        | 0        | 0        | 0        | 0        | 0        | 0         | 0         | 0          |
| 33   | 0         | 0.264    | 0.012    | 0        | 0        | 0        | 0        | 0        | 0        | 0         | 0         | 0          |
| 30   | 0         | 0.244    | 0.002    | 0        | 0        | 0        | 0        | 0        | 0        | 0         | 0         | 0          |
| 27   | 0.002     | 0.143    | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0         | 0         | 0          |
| 24   | 0.021     | 0.053    | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0         | 0         | 0          |
| 21   | 0.104     | 0.012    | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0         | 0         | 0          |
| 18   | 0.258     | 0.002    | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0         | 0         | 0          |
| 15   | 0.326     | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0         | 0         | 0          |
| 12   | 0.209     | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0         | 0         | 0          |
| 9    | 0.080     | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0         | 0         | 0          |

Table 2.22—Schedules of Pacific cod weight (kg) and maturity proportions at length (cm) as defined by final parameter estimates. Lengths correspond to lower bounds of size bins.

| Bin | Length | Weight | Maturity |
|-----|--------|--------|----------|
| 1   | 9      | 0.01   | 0.00     |
| 2   | 12     | 0.02   | 0.00     |
| 3   | 15     | 0.04   | 0.00     |
| 4   | 18     | 0.07   | 0.00     |
| 5   | 21     | 0.11   | 0.00     |
| 6   | 24     | 0.16   | 0.00     |
| 7   | 27     | 0.23   | 0.00     |
| 8   | 30     | 0.32   | 0.01     |
| 9   | 33     | 0.43   | 0.01     |
| 10  | 36     | 0.56   | 0.02     |
| 11  | 39     | 0.71   | 0.02     |
| 12  | 42     | 0.90   | 0.04     |
| 13  | 45     | 1.20   | 0.06     |
| 14  | 50     | 1.66   | 0.12     |
| 15  | 55     | 2.23   | 0.21     |
| 16  | 60     | 2.91   | 0.35     |
| 17  | 65     | 3.74   | 0.51     |
| 18  | 70     | 4.71   | 0.68     |
| 19  | 75     | 5.84   | 0.81     |
| 20  | 80     | 7.15   | 0.89     |
| 21  | 85     | 8.65   | 0.95     |
| 22  | 90     | 10.35  | 0.97     |
| 23  | 95     | 12.27  | 0.99     |
| 24  | 100    | 14.43  | 0.99     |
| 25  | 105    | 15.57  | 1.00     |

Table 2.23—Schedules of Pacific cod selectivities as defined by final parameter estimates. Lengths (cm) correspond to lower bounds of size bins.

| Bin | Len. | Trawl (Jan.-May) |                | Trawl (Jun.-Dec.) |                | Longline       |                | Pot            | Survey         |                |
|-----|------|------------------|----------------|-------------------|----------------|----------------|----------------|----------------|----------------|----------------|
|     |      | <u>1978-88</u>   | <u>1989-01</u> | <u>1978-88</u>    | <u>1989-01</u> | <u>1978-88</u> | <u>1989-01</u> | <u>1989-01</u> | <u>1978-81</u> | <u>1982-01</u> |
| 1   | 9    | 0.00             | 0.00           | 0.00              | 0.00           | 0.00           | 0.00           | 0.00           | 0.00           | 0.13           |
| 2   | 12   | 0.00             | 0.00           | 0.00              | 0.00           | 0.00           | 0.00           | 0.00           | 0.02           | 0.21           |
| 3   | 15   | 0.00             | 0.00           | 0.00              | 0.00           | 0.00           | 0.00           | 0.00           | 0.06           | 0.29           |
| 4   | 18   | 0.01             | 0.01           | 0.00              | 0.00           | 0.00           | 0.00           | 0.00           | 0.12           | 0.37           |
| 5   | 21   | 0.01             | 0.01           | 0.00              | 0.01           | 0.00           | 0.00           | 0.00           | 0.22           | 0.45           |
| 6   | 24   | 0.02             | 0.02           | 0.01              | 0.01           | 0.00           | 0.00           | 0.00           | 0.36           | 0.54           |
| 7   | 27   | 0.04             | 0.03           | 0.01              | 0.02           | 0.00           | 0.00           | 0.00           | 0.52           | 0.62           |
| 8   | 30   | 0.06             | 0.05           | 0.02              | 0.03           | 0.00           | 0.00           | 0.00           | 0.68           | 0.70           |
| 9   | 33   | 0.09             | 0.08           | 0.03              | 0.05           | 0.01           | 0.01           | 0.00           | 0.81           | 0.78           |
| 10  | 36   | 0.14             | 0.11           | 0.05              | 0.10           | 0.01           | 0.02           | 0.01           | 0.90           | 0.86           |
| 11  | 39   | 0.21             | 0.17           | 0.07              | 0.17           | 0.03           | 0.03           | 0.01           | 0.96           | 0.94           |
| 12  | 42   | 0.30             | 0.24           | 0.12              | 0.27           | 0.05           | 0.07           | 0.03           | 1.00           | 0.98           |
| 13  | 45   | 0.40             | 0.32           | 0.18              | 0.41           | 0.11           | 0.14           | 0.06           | 0.88           | 0.90           |
| 14  | 50   | 0.60             | 0.49           | 0.33              | 0.66           | 0.29           | 0.39           | 0.20           | 0.69           | 0.78           |
| 15  | 55   | 0.77             | 0.67           | 0.54              | 0.85           | 0.58           | 0.71           | 0.49           | 0.55           | 0.66           |
| 16  | 60   | 0.89             | 0.81           | 0.73              | 0.94           | 0.82           | 0.91           | 0.79           | 0.46           | 0.55           |
| 17  | 65   | 0.95             | 0.91           | 0.87              | 0.98           | 0.94           | 0.98           | 0.94           | 0.41           | 0.45           |
| 18  | 70   | 0.98             | 0.96           | 0.95              | 0.99           | 0.99           | 0.97           | 0.99           | 0.38           | 0.37           |
| 19  | 75   | 1.00             | 0.99           | 0.99              | 1.00           | 1.00           | 0.82           | 0.87           | 0.36           | 0.30           |
| 20  | 80   | 0.95             | 0.93           | 0.93              | 1.00           | 0.84           | 0.67           | 0.73           | 0.36           | 0.24           |
| 21  | 85   | 0.74             | 0.87           | 0.91              | 1.00           | 0.66           | 0.60           | 0.67           | 0.35           | 0.19           |
| 22  | 90   | 0.60             | 0.87           | 0.91              | 1.00           | 0.52           | 0.57           | 0.65           | 0.35           | 0.15           |
| 23  | 95   | 0.56             | 0.87           | 0.91              | 1.00           | 0.43           | 0.56           | 0.64           | 0.35           | 0.12           |
| 24  | 100  | 0.55             | 0.87           | 0.91              | 1.00           | 0.38           | 0.56           | 0.64           | 0.35           | 0.09           |
| 25  | 105  | 0.55             | 0.87           | 0.91              | 1.00           | 0.36           | 0.56           | 0.64           | 0.35           | 0.08           |

Table 2.24—Time series of EBS Pacific cod age 3+ biomass, spawning biomass, and survey biomass as estimated in last year's and this year's assessments.

| Year | Age 3+ Biomass   |                  | Spawning Biomass |                  | Survey Biomass   |                  |
|------|------------------|------------------|------------------|------------------|------------------|------------------|
|      | <u>Last Year</u> | <u>This Year</u> | <u>Last Year</u> | <u>This Year</u> | <u>Last Year</u> | <u>This Year</u> |
| 1978 | 331              | 323              | 49               | 48               | n/a              | n/a              |
| 1979 | 486              | 475              | 80               | 79               | 572              | 564              |
| 1980 | 1072             | 1054             | 138              | 135              | 923              | 918              |
| 1981 | 1584             | 1566             | 253              | 250              | 1056             | 1058             |
| 1982 | 2041             | 2025             | 428              | 426              | 1194             | 1188             |
| 1983 | 2357             | 2345             | 600              | 599              | 1118             | 1114             |
| 1984 | 2381             | 2374             | 714              | 714              | 1081             | 1075             |
| 1985 | 2534             | 2528             | 753              | 753              | 1110             | 1105             |
| 1986 | 2491             | 2489             | 754              | 755              | 1099             | 1094             |
| 1987 | 2566             | 2566             | 756              | 759              | 1120             | 1118             |
| 1988 | 2560             | 2564             | 752              | 755              | 1027             | 1027             |
| 1989 | 2407             | 2415             | 738              | 742              | 863              | 864              |
| 1990 | 2155             | 2165             | 709              | 715              | 712              | 711              |
| 1991 | 1882             | 1892             | 642              | 648              | 658              | 656              |
| 1992 | 1708             | 1719             | 544              | 549              | 712              | 712              |
| 1993 | 1678             | 1691             | 474              | 480              | 750              | 753              |
| 1994 | 1666             | 1682             | 461              | 467              | 773              | 778              |
| 1995 | 1704             | 1725             | 450              | 457              | 762              | 771              |
| 1996 | 1620             | 1646             | 436              | 444              | 679              | 691              |
| 1997 | 1494             | 1524             | 422              | 432              | 580              | 594              |
| 1998 | 1304             | 1340             | 392              | 403              | 552              | 575              |
| 1999 | 1272             | 1324             | 359              | 373              | 560              | 607              |
| 2000 | 1225             | 1318             | 338              | 355              | 515              | 598              |
| 2001 | n/a              | 1273             | n/a              | 356              | n/a              | 609              |

Notes: Spawning biomass is computed as the sum of March female numbers at age times population weight at age times fraction mature at age.

“Survey biomass” is the model’s estimate of what the actual survey should have observed.

All biomass figures are in 1000s of t.

Table 2.25—Time series of EBS Pacific cod age 3 recruitment as estimated in last year's and this year's assessments.

| Year | Recruitment (millions of age 3 fish) |                  |
|------|--------------------------------------|------------------|
|      | <u>Last Year</u>                     | <u>This Year</u> |
| 1978 | 92                                   | 92               |
| 1979 | 177                                  | 173              |
| 1980 | 704                                  | 696              |
| 1981 | 312                                  | 311              |
| 1982 | 354                                  | 353              |
| 1983 | 281                                  | 281              |
| 1984 | 91                                   | 91               |
| 1985 | 517                                  | 515              |
| 1986 | 152                                  | 153              |
| 1987 | 420                                  | 418              |
| 1988 | 255                                  | 257              |
| 1989 | 159                                  | 159              |
| 1990 | 91                                   | 91               |
| 1991 | 122                                  | 121              |
| 1992 | 291                                  | 292              |
| 1993 | 284                                  | 287              |
| 1994 | 165                                  | 167              |
| 1995 | 322                                  | 324              |
| 1996 | 155                                  | 159              |
| 1997 | 129                                  | 132              |
| 1998 | 117                                  | 125              |
| 1999 | 250                                  | 269              |
| 2000 | 130                                  | 174              |
| 2001 | n/a                                  | 128              |

Table 2.26—Time series of EBS Pacific cod catch divided by age 3+ biomass as estimated in last year’s and this year’s assessments (the entry for 2001 under “This Year” is based on catch through August, 2001; the entry for 2000 under “Last Year” was based on catch through August, 2000).

| Year | EBS Catch Divided by Age 3+ Biomass |                  |
|------|-------------------------------------|------------------|
|      | <u>Last Year</u>                    | <u>This Year</u> |
| 1978 | 0.13                                | 0.13             |
| 1979 | 0.07                                | 0.07             |
| 1980 | 0.04                                | 0.04             |
| 1981 | 0.04                                | 0.04             |
| 1982 | 0.03                                | 0.03             |
| 1983 | 0.04                                | 0.04             |
| 1984 | 0.05                                | 0.05             |
| 1985 | 0.06                                | 0.06             |
| 1986 | 0.05                                | 0.05             |
| 1987 | 0.06                                | 0.06             |
| 1988 | 0.08                                | 0.08             |
| 1989 | 0.07                                | 0.07             |
| 1990 | 0.08                                | 0.08             |
| 1991 | 0.11                                | 0.11             |
| 1992 | 0.10                                | 0.10             |
| 1993 | 0.08                                | 0.08             |
| 1994 | 0.10                                | 0.10             |
| 1995 | 0.13                                | 0.13             |
| 1996 | 0.13                                | 0.13             |
| 1997 | 0.16                                | 0.15             |
| 1998 | 0.12                                | 0.12             |
| 1999 | 0.11                                | 0.11             |
| 2000 | 0.08                                | 0.11             |
| 2001 | n/a                                 | 0.07             |

Table 2.27—Age structure of the total and spawning populations of EBS Pacific cod.

| Total numbers at age (millions) |          |          |          |          |          |          |          |          |          |           |           |           |      |
|---------------------------------|----------|----------|----------|----------|----------|----------|----------|----------|----------|-----------|-----------|-----------|------|
| Year                            | Age      |          |          |          |          |          |          |          |          |           |           |           | Sum  |
|                                 | <u>1</u> | <u>2</u> | <u>3</u> | <u>4</u> | <u>5</u> | <u>6</u> | <u>7</u> | <u>8</u> | <u>9</u> | <u>10</u> | <u>11</u> | <u>12</u> |      |
| 1978                            | 1465     | 253      | 92       | 103      | 0        | 11       | 3        | 0        | 0        | 0         | 1         | 0         | 1047 |
| 1979                            | 654      | 1012     | 173      | 60       | 63       | 0        | 6        | 2        | 0        | 0         | 0         | 0         | 929  |
| 1980                            | 742      | 452      | 696      | 117      | 39       | 40       | 0        | 4        | 1        | 0         | 0         | 0         | 966  |
| 1981                            | 590      | 513      | 311      | 473      | 77       | 25       | 26       | 0        | 2        | 1         | 0         | 0         | 970  |
| 1982                            | 190      | 407      | 353      | 212      | 317      | 51       | 17       | 17       | 0        | 2         | 1         | 0         | 892  |
| 1983                            | 1082     | 132      | 281      | 242      | 143      | 212      | 34       | 11       | 11       | 0         | 1         | 0         | 855  |
| 1984                            | 321      | 747      | 91       | 192      | 162      | 95       | 140      | 22       | 7        | 7         | 0         | 1         | 812  |
| 1985                            | 879      | 222      | 515      | 62       | 127      | 106      | 62       | 91       | 15       | 5         | 5         | 1         | 949  |
| 1986                            | 540      | 607      | 153      | 349      | 41       | 82       | 68       | 39       | 58       | 9         | 3         | 4         | 908  |
| 1987                            | 335      | 373      | 418      | 104      | 231      | 26       | 53       | 44       | 26       | 38        | 6         | 4         | 859  |
| 1988                            | 191      | 231      | 257      | 283      | 68       | 148      | 17       | 34       | 28       | 17        | 25        | 7         | 944  |
| 1989                            | 254      | 132      | 159      | 172      | 183      | 43       | 92       | 10       | 21       | 18        | 10        | 20        | 900  |
| 1990                            | 614      | 176      | 91       | 107      | 112      | 117      | 27       | 58       | 7        | 13        | 11        | 19        | 952  |
| 1991                            | 604      | 424      | 121      | 61       | 69       | 71       | 73       | 17       | 37       | 4         | 9         | 19        | 902  |
| 1992                            | 352      | 417      | 292      | 80       | 38       | 42       | 43       | 44       | 10       | 22        | 3         | 17        | 824  |
| 1993                            | 683      | 243      | 287      | 196      | 51       | 23       | 25       | 26       | 27       | 6         | 14        | 12        | 737  |
| 1994                            | 334      | 472      | 167      | 194      | 127      | 32       | 14       | 16       | 16       | 17        | 4         | 16        | 684  |
| 1995                            | 279      | 231      | 324      | 112      | 123      | 77       | 19       | 9        | 10       | 10        | 10        | 13        | 663  |
| 1996                            | 263      | 192      | 159      | 215      | 69       | 71       | 44       | 11       | 5        | 6         | 6         | 14        | 719  |
| 1997                            | 567      | 181      | 132      | 106      | 134      | 41       | 42       | 26       | 7        | 3         | 3         | 12        | 670  |
| 1998                            | 365      | 392      | 125      | 87       | 64       | 76       | 23       | 24       | 15       | 4         | 2         | 9         | 605  |
| 1999                            | 270      | 252      | 269      | 83       | 55       | 38       | 45       | 14       | 14       | 9         | 2         | 7         | 570  |
| 2000                            | 550      | 186      | 174      | 180      | 52       | 32       | 23       | 27       | 8        | 9         | 6         | 5         | 540  |

| Spawning numbers at age (millions) |     |     |      |      |      |      |      |      |      |      |      |     |       |
|------------------------------------|-----|-----|------|------|------|------|------|------|------|------|------|-----|-------|
| Year                               | Age |     |      |      |      |      |      |      |      |      |      |     | Sum   |
|                                    | 1   | 2   | 3    | 4    | 5    | 6    | 7    | 8    | 9    | 10   | 11   | 12  |       |
| 1978                               | 0.0 | 1.3 | 2.8  | 11.6 | 0.0  | 3.8  | 1.4  | 0.0  | 0.0  | 0.0  | 0.3  | 0.0 | 21.3  |
| 1979                               | 0.0 | 5.1 | 5.2  | 6.7  | 15.1 | 0.0  | 2.5  | 0.9  | 0.0  | 0.0  | 0.0  | 0.2 | 35.8  |
| 1980                               | 0.0 | 2.3 | 20.9 | 13.1 | 9.4  | 13.9 | 0.0  | 1.7  | 0.6  | 0.0  | 0.0  | 0.2 | 62.0  |
| 1981                               | 0.0 | 2.6 | 9.3  | 53.0 | 18.6 | 8.9  | 10.8 | 0.0  | 1.2  | 0.4  | 0.0  | 0.1 | 104.9 |
| 1982                               | 0.0 | 2.0 | 10.6 | 23.8 | 76.1 | 18.0 | 7.0  | 7.7  | 0.0  | 0.8  | 0.3  | 0.1 | 146.3 |
| 1983                               | 0.0 | 0.7 | 8.4  | 27.1 | 34.4 | 74.4 | 14.3 | 5.1  | 5.4  | 0.0  | 0.5  | 0.2 | 170.4 |
| 1984                               | 0.0 | 3.7 | 2.7  | 21.5 | 38.9 | 33.3 | 58.3 | 10.2 | 3.5  | 3.6  | 0.0  | 0.5 | 176.2 |
| 1985                               | 0.0 | 1.1 | 15.4 | 6.9  | 30.5 | 37.1 | 25.7 | 41.1 | 6.9  | 2.3  | 2.4  | 0.3 | 169.9 |
| 1986                               | 0.0 | 3.0 | 4.6  | 39.1 | 9.7  | 28.8 | 28.3 | 17.9 | 27.6 | 4.6  | 1.5  | 1.8 | 167.0 |
| 1987                               | 0.0 | 1.9 | 12.6 | 11.6 | 55.3 | 9.2  | 22.1 | 19.8 | 12.1 | 18.3 | 3.0  | 2.2 | 168.1 |
| 1988                               | 0.0 | 1.2 | 7.7  | 31.7 | 16.3 | 52.0 | 7.0  | 15.3 | 13.3 | 8.0  | 12.0 | 3.4 | 168.0 |
| 1989                               | 0.0 | 0.7 | 4.8  | 19.3 | 43.9 | 15.0 | 38.6 | 4.8  | 10.0 | 8.5  | 5.1  | 9.7 | 160.4 |
| 1990                               | 0.0 | 0.9 | 2.7  | 12.0 | 27.0 | 40.9 | 11.3 | 26.5 | 3.1  | 6.5  | 5.5  | 9.4 | 145.8 |
| 1991                               | 0.0 | 2.1 | 3.6  | 6.8  | 16.6 | 24.9 | 30.6 | 7.7  | 17.4 | 2.0  | 4.1  | 9.4 | 125.5 |
| 1992                               | 0.0 | 2.1 | 8.8  | 9.0  | 9.2  | 14.7 | 17.8 | 20.0 | 4.9  | 10.8 | 1.3  | 8.3 | 106.8 |
| 1993                               | 0.0 | 1.2 | 8.6  | 21.9 | 12.2 | 8.2  | 10.6 | 11.7 | 12.8 | 3.1  | 6.8  | 5.9 | 103.1 |
| 1994                               | 0.0 | 2.4 | 5.0  | 21.7 | 30.4 | 11.2 | 6.0  | 7.1  | 7.6  | 8.2  | 2.0  | 8.0 | 109.5 |
| 1995                               | 0.0 | 1.2 | 9.7  | 12.5 | 29.4 | 27.0 | 8.0  | 4.0  | 4.5  | 4.8  | 5.1  | 6.2 | 112.5 |
| 1996                               | 0.0 | 1.0 | 4.8  | 24.1 | 16.5 | 25.1 | 18.5 | 5.1  | 2.4  | 2.7  | 2.9  | 6.7 | 109.8 |
| 1997                               | 0.0 | 0.9 | 4.0  | 11.8 | 32.1 | 14.3 | 17.4 | 11.8 | 3.1  | 1.5  | 1.7  | 5.8 | 104.4 |
| 1998                               | 0.0 | 2.0 | 3.7  | 9.8  | 15.4 | 26.8 | 9.6  | 10.8 | 7.1  | 1.9  | 0.9  | 4.4 | 92.3  |
| 1999                               | 0.0 | 1.3 | 8.1  | 9.3  | 13.1 | 13.4 | 18.9 | 6.2  | 6.8  | 4.4  | 1.1  | 3.2 | 85.7  |
| 2000                               | 0.0 | 0.9 | 5.2  | 20.2 | 12.5 | 11.4 | 9.4  | 12.2 | 3.9  | 4.2  | 2.7  | 2.7 | 85.3  |

Table 2.28—Calculation of the correlation (*Cor*, shown in the bottom-right cell of each half of the table) between two indices of stock structure “breadth” and subsequent age 1 recruitment  $R(t+1)$ .

| Shannon-Wiener information index |          |          |          |          |          |          |          |          |          |           |           |           | Index | $R(t+1)$ |
|----------------------------------|----------|----------|----------|----------|----------|----------|----------|----------|----------|-----------|-----------|-----------|-------|----------|
| Year                             | Age      |          |          |          |          |          |          |          |          |           |           |           |       |          |
|                                  | <u>1</u> | <u>2</u> | <u>3</u> | <u>4</u> | <u>5</u> | <u>6</u> | <u>7</u> | <u>8</u> | <u>9</u> | <u>10</u> | <u>11</u> | <u>12</u> |       |          |
| 1978                             | 0.000    | 0.168    | 0.264    | 0.332    | 0.008    | 0.306    | 0.181    | 0.013    | 0.014    | 0.014     | 0.062     | 0.014     | 1.376 | 654      |
| 1979                             | 0.000    | 0.276    | 0.280    | 0.314    | 0.364    | 0.004    | 0.188    | 0.091    | 0.005    | 0.006     | 0.006     | 0.030     | 1.565 | 742      |
| 1980                             | 0.000    | 0.121    | 0.367    | 0.328    | 0.286    | 0.335    | 0.002    | 0.100    | 0.043    | 0.002     | 0.002     | 0.015     | 1.601 | 590      |
| 1981                             | 0.000    | 0.091    | 0.215    | 0.345    | 0.307    | 0.210    | 0.234    | 0.001    | 0.050    | 0.020     | 0.001     | 0.007     | 1.481 | 190      |
| 1982                             | 0.000    | 0.060    | 0.190    | 0.295    | 0.340    | 0.258    | 0.146    | 0.155    | 0.000    | 0.028     | 0.011     | 0.004     | 1.487 | 1082     |
| 1983                             | 0.000    | 0.021    | 0.149    | 0.292    | 0.323    | 0.362    | 0.208    | 0.105    | 0.109    | 0.000     | 0.018     | 0.009     | 1.595 | 321      |
| 1984                             | 0.000    | 0.082    | 0.064    | 0.256    | 0.333    | 0.315    | 0.366    | 0.165    | 0.078    | 0.080     | 0.000     | 0.017     | 1.756 | 879      |
| 1985                             | 0.000    | 0.033    | 0.218    | 0.130    | 0.308    | 0.332    | 0.286    | 0.343    | 0.130    | 0.059     | 0.060     | 0.012     | 1.912 | 540      |
| 1986                             | 0.000    | 0.073    | 0.099    | 0.340    | 0.166    | 0.303    | 0.301    | 0.240    | 0.298    | 0.098     | 0.043     | 0.048     | 2.008 | 335      |
| 1987                             | 0.000    | 0.050    | 0.194    | 0.185    | 0.366    | 0.159    | 0.267    | 0.252    | 0.189    | 0.241     | 0.072     | 0.056     | 2.031 | 191      |
| 1988                             | 0.000    | 0.034    | 0.141    | 0.315    | 0.227    | 0.363    | 0.133    | 0.219    | 0.201    | 0.145     | 0.189     | 0.078     | 2.044 | 254      |
| 1989                             | 0.000    | 0.023    | 0.105    | 0.255    | 0.355    | 0.222    | 0.343    | 0.104    | 0.173    | 0.156     | 0.109     | 0.170     | 2.014 | 614      |
| 1990                             | 0.000    | 0.031    | 0.074    | 0.205    | 0.312    | 0.357    | 0.199    | 0.310    | 0.083    | 0.138     | 0.123     | 0.177     | 2.009 | 604      |
| 1991                             | 0.000    | 0.069    | 0.102    | 0.159    | 0.268    | 0.321    | 0.344    | 0.172    | 0.274    | 0.067     | 0.113     | 0.195     | 2.083 | 352      |
| 1992                             | 0.000    | 0.077    | 0.205    | 0.209    | 0.211    | 0.273    | 0.298    | 0.314    | 0.141    | 0.232     | 0.052     | 0.199     | 2.211 | 683      |
| 1993                             | 0.000    | 0.052    | 0.207    | 0.329    | 0.253    | 0.201    | 0.234    | 0.247    | 0.259    | 0.105     | 0.179     | 0.165     | 2.231 | 334      |
| 1994                             | 0.000    | 0.083    | 0.141    | 0.321    | 0.356    | 0.233    | 0.160    | 0.178    | 0.186    | 0.194     | 0.072     | 0.191     | 2.113 | 279      |
| 1995                             | 0.000    | 0.047    | 0.212    | 0.245    | 0.351    | 0.343    | 0.189    | 0.118    | 0.130    | 0.134     | 0.140     | 0.159     | 2.066 | 263      |
| 1996                             | 0.000    | 0.042    | 0.136    | 0.333    | 0.285    | 0.337    | 0.300    | 0.142    | 0.084    | 0.092     | 0.095     | 0.170     | 2.017 | 567      |
| 1997                             | 0.000    | 0.041    | 0.124    | 0.247    | 0.363    | 0.272    | 0.299    | 0.247    | 0.105    | 0.060     | 0.066     | 0.160     | 1.984 | 365      |
| 1998                             | 0.000    | 0.082    | 0.130    | 0.238    | 0.299    | 0.359    | 0.235    | 0.251    | 0.198    | 0.079     | 0.044     | 0.144     | 2.058 | 270      |
| 1999                             | 0.000    | 0.062    | 0.223    | 0.241    | 0.287    | 0.290    | 0.333    | 0.190    | 0.200    | 0.152     | 0.058     | 0.123     | 2.159 | 550      |
| 2000                             | 0.000    | 0.049    | 0.171    | 0.341    | 0.281    | 0.269    | 0.243    | 0.278    | 0.141    | 0.148     | 0.109     | 0.108     | 2.139 | 770      |

*Cor:* -0.324

| Simpson diversity index |       |       |       |       |       |       |       |       |       |       |       |       | Index | $R(t+1)$ |
|-------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|----------|
| Year                    | Age   |       |       |       |       |       |       |       |       |       |       |       |       |          |
|                         | 1     | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     | 10    | 11    | 12    |       |          |
| 1978                    | 0.000 | 0.004 | 0.017 | 0.295 | 0.000 | 0.031 | 0.004 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.649 | 654      |
| 1979                    | 0.000 | 0.020 | 0.021 | 0.035 | 0.177 | 0.000 | 0.005 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.740 | 742      |
| 1980                    | 0.000 | 0.001 | 0.114 | 0.044 | 0.023 | 0.050 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.767 | 590      |
| 1981                    | 0.000 | 0.001 | 0.008 | 0.255 | 0.031 | 0.007 | 0.011 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.687 | 190      |
| 1982                    | 0.000 | 0.000 | 0.005 | 0.026 | 0.270 | 0.015 | 0.002 | 0.003 | 0.000 | 0.000 | 0.000 | 0.000 | 0.678 | 1082     |
| 1983                    | 0.000 | 0.000 | 0.002 | 0.025 | 0.041 | 0.191 | 0.007 | 0.001 | 0.001 | 0.000 | 0.000 | 0.000 | 0.732 | 321      |
| 1984                    | 0.000 | 0.000 | 0.000 | 0.015 | 0.049 | 0.036 | 0.110 | 0.003 | 0.000 | 0.000 | 0.000 | 0.000 | 0.786 | 879      |
| 1985                    | 0.000 | 0.000 | 0.008 | 0.002 | 0.032 | 0.048 | 0.023 | 0.059 | 0.002 | 0.000 | 0.000 | 0.000 | 0.826 | 540      |
| 1986                    | 0.000 | 0.000 | 0.001 | 0.055 | 0.003 | 0.030 | 0.029 | 0.012 | 0.027 | 0.001 | 0.000 | 0.000 | 0.842 | 335      |
| 1987                    | 0.000 | 0.000 | 0.006 | 0.005 | 0.108 | 0.003 | 0.017 | 0.014 | 0.005 | 0.012 | 0.000 | 0.000 | 0.829 | 191      |
| 1988                    | 0.000 | 0.000 | 0.002 | 0.036 | 0.009 | 0.096 | 0.002 | 0.008 | 0.006 | 0.002 | 0.005 | 0.000 | 0.833 | 254      |
| 1989                    | 0.000 | 0.000 | 0.001 | 0.014 | 0.075 | 0.009 | 0.058 | 0.001 | 0.004 | 0.003 | 0.001 | 0.004 | 0.831 | 614      |
| 1990                    | 0.000 | 0.000 | 0.000 | 0.007 | 0.034 | 0.079 | 0.006 | 0.033 | 0.000 | 0.002 | 0.001 | 0.004 | 0.833 | 604      |
| 1991                    | 0.000 | 0.000 | 0.001 | 0.003 | 0.018 | 0.039 | 0.059 | 0.004 | 0.019 | 0.000 | 0.001 | 0.006 | 0.849 | 352      |
| 1992                    | 0.000 | 0.000 | 0.007 | 0.007 | 0.007 | 0.019 | 0.028 | 0.035 | 0.002 | 0.010 | 0.000 | 0.006 | 0.878 | 683      |
| 1993                    | 0.000 | 0.000 | 0.007 | 0.045 | 0.014 | 0.006 | 0.011 | 0.013 | 0.015 | 0.001 | 0.004 | 0.003 | 0.880 | 334      |
| 1994                    | 0.000 | 0.000 | 0.002 | 0.039 | 0.077 | 0.010 | 0.003 | 0.004 | 0.005 | 0.006 | 0.000 | 0.005 | 0.848 | 279      |
| 1995                    | 0.000 | 0.000 | 0.007 | 0.012 | 0.068 | 0.058 | 0.005 | 0.001 | 0.002 | 0.002 | 0.002 | 0.003 | 0.839 | 263      |
| 1996                    | 0.000 | 0.000 | 0.002 | 0.048 | 0.023 | 0.052 | 0.029 | 0.002 | 0.000 | 0.001 | 0.001 | 0.004 | 0.839 | 567      |
| 1997                    | 0.000 | 0.000 | 0.001 | 0.013 | 0.095 | 0.019 | 0.028 | 0.013 | 0.001 | 0.000 | 0.000 | 0.003 | 0.827 | 365      |
| 1998                    | 0.000 | 0.000 | 0.002 | 0.011 | 0.028 | 0.085 | 0.011 | 0.014 | 0.006 | 0.000 | 0.000 | 0.002 | 0.841 | 270      |
| 1999                    | 0.000 | 0.000 | 0.009 | 0.012 | 0.023 | 0.024 | 0.048 | 0.005 | 0.006 | 0.003 | 0.000 | 0.001 | 0.867 | 550      |
| 2000                    | 0.000 | 0.000 | 0.004 | 0.056 | 0.021 | 0.018 | 0.012 | 0.020 | 0.002 | 0.002 | 0.001 | 0.001 | 0.862 | 770      |

*Cor:* -0.294

Table 2.29—Definitions of symbols and terms used in the Pacific cod projection tables.

| Symbol   | Definition   |
|----------|--|
| SPR      | Equilibrium spawning per recruit, expressed as a percentage of the maximum level     |
| L90%CI   | Lower bound of the 90% confidence interval   |
| Median   | Point that divides projection outputs into two groups of equal size (50% higher, 50% |
| Mean     | Average value of the projection outputs  |
| U90%CI   | Upper bound of the 90% confidence interval   |
| St. Dev. | Standard deviation of the projection outputs   |

Table 2.30—Equilibrium reference points and projections for BSAI Pacific cod spawning biomass (1000s of t), fishing mortality, and catch (1000s of t) under the assumption that  $F = \max F_{ABC}$  in each year 2002-2014, where future recruitment is drawn from a distribution based on estimated recruitments spawned during the period 1977-2000. See Table 2.29 for symbol definitions.

**Equilibrium Reference Points**

| SPR  | Spawning Biomass | Fishing Mortality | Catch |
|------|------------------|-------------------|-------|
| 100% | 1,080            | 0                 | 0     |
| 40%  | 431              | 0.30              | 286   |
| 35%  | 377              | 0.36              | 305   |

**Spawning Biomass Projections**

| Year | L90%CI | Median | Mean  | U90%CI | St. Dev. |
|------|--------|--------|-------|--------|----------|
| 2002 | 425.4  | 425.4  | 425.4 | 425.4  | 0.00     |
| 2003 | 394.6  | 394.8  | 394.9 | 395.4  | 0.26     |
| 2004 | 402.8  | 406.2  | 407.1 | 414.4  | 3.85     |
| 2005 | 412.6  | 430.9  | 435.6 | 473.1  | 20.20    |
| 2006 | 394.4  | 439.5  | 448.8 | 532.5  | 46.01    |
| 2007 | 368.6  | 437.0  | 449.2 | 567.6  | 65.33    |
| 2008 | 351.4  | 433.3  | 446.9 | 582.5  | 75.12    |
| 2009 | 345.4  | 430.5  | 444.8 | 585.2  | 78.91    |
| 2010 | 340.5  | 428.5  | 443.5 | 591.7  | 79.57    |
| 2011 | 339.9  | 428.3  | 442.7 | 599.2  | 79.67    |
| 2012 | 342.3  | 426.3  | 443.0 | 592.3  | 79.87    |
| 2013 | 339.8  | 428.1  | 443.3 | 586.4  | 79.69    |
| 2014 | 343.5  | 428.9  | 443.8 | 596.3  | 78.79    |

**Fishing Mortality Projections**

| Year | L90%CI | Median | Mean | U90%CI | St. Dev. |
|------|--------|--------|------|--------|----------|
| 2002 | 0.30   | 0.30   | 0.30 | 0.30   | 0.000    |
| 2003 | 0.27   | 0.27   | 0.27 | 0.27   | 0.000    |
| 2004 | 0.28   | 0.28   | 0.28 | 0.29   | 0.003    |
| 2005 | 0.29   | 0.30   | 0.30 | 0.30   | 0.005    |
| 2006 | 0.27   | 0.30   | 0.29 | 0.30   | 0.010    |
| 2007 | 0.25   | 0.30   | 0.29 | 0.30   | 0.016    |
| 2008 | 0.24   | 0.30   | 0.29 | 0.30   | 0.020    |
| 2009 | 0.24   | 0.30   | 0.28 | 0.30   | 0.023    |
| 2010 | 0.23   | 0.30   | 0.28 | 0.30   | 0.024    |
| 2011 | 0.23   | 0.30   | 0.28 | 0.30   | 0.024    |
| 2012 | 0.24   | 0.30   | 0.28 | 0.30   | 0.024    |
| 2013 | 0.23   | 0.30   | 0.28 | 0.30   | 0.023    |
| 2014 | 0.24   | 0.30   | 0.28 | 0.30   | 0.023    |

**Catch Projections**

| Year | L90%CI | Median | Mean  | U90%CI | St. Dev. |
|------|--------|--------|-------|--------|----------|
| 2002 | 253.5  | 253.5  | 253.5 | 253.5  | 0.00     |
| 2003 | 230.5  | 230.9  | 231.0 | 231.8  | 0.45     |
| 2004 | 256.8  | 264.3  | 266.2 | 282.4  | 8.45     |
| 2005 | 259.2  | 295.4  | 298.9 | 353.8  | 30.50    |
| 2006 | 223.3  | 292.9  | 296.4 | 384.4  | 51.67    |
| 2007 | 193.3  | 286.3  | 287.6 | 401.0  | 64.51    |
| 2008 | 176.7  | 281.5  | 282.0 | 395.8  | 70.31    |
| 2009 | 169.4  | 277.3  | 279.5 | 398.3  | 72.21    |
| 2010 | 165.5  | 278.8  | 278.2 | 402.9  | 72.67    |
| 2011 | 167.1  | 275.0  | 277.4 | 404.1  | 72.95    |
| 2012 | 168.6  | 277.0  | 278.4 | 400.4  | 72.84    |
| 2013 | 167.8  | 277.5  | 278.9 | 398.7  | 72.21    |
| 2014 | 170.0  | 276.6  | 279.7 | 400.6  | 71.66    |

Table 2.31—Equilibrium reference points and projections for BSAI Pacific cod spawning biomass (1000s of t), fishing mortality, and catch (1000s of t) under the assumption that the ratio of  $F$  to  $\max F_{ABC}$  in each year 2002-2014 is fixed at a value of 0.87, where future recruitment is drawn from a distribution based on estimated recruitments spawned during the period 1977-2000. See Table 2.29 for symbol definitions.

#### Equilibrium Reference Points

| SPR  | Spawning Biomass | Fishing Mortality | Catch |
|------|------------------|-------------------|-------|
| 100% | 1,080            | 0                 | 0     |
| 40%  | 431              | 0.30              | 286   |
| 35%  | 377              | 0.36              | 305   |

#### Spawning Biomass Projections

| Year | L90%CI | Median | Mean  | U90%CI | St. Dev. |
|------|--------|--------|-------|--------|----------|
| 2002 | 427.6  | 427.6  | 427.6 | 427.6  | 0.00     |
| 2003 | 407.0  | 407.2  | 407.3 | 407.8  | 0.26     |
| 2004 | 420.5  | 424.0  | 424.9 | 432.3  | 3.90     |
| 2005 | 434.4  | 453.6  | 458.1 | 496.3  | 20.73    |
| 2006 | 418.7  | 468.8  | 478.0 | 565.2  | 48.57    |
| 2007 | 392.6  | 472.6  | 483.0 | 611.4  | 70.67    |
| 2008 | 375.0  | 469.7  | 483.0 | 631.9  | 82.80    |
| 2009 | 366.5  | 466.7  | 481.8 | 634.1  | 88.10    |
| 2010 | 363.4  | 467.1  | 480.6 | 645.4  | 89.58    |
| 2011 | 361.5  | 466.4  | 479.9 | 654.1  | 90.03    |
| 2012 | 363.6  | 464.8  | 480.0 | 646.9  | 90.30    |
| 2013 | 362.3  | 464.3  | 480.2 | 640.9  | 90.04    |
| 2014 | 365.4  | 468.0  | 480.7 | 650.6  | 89.07    |

#### Fishing Mortality Projections

| Year | L90%CI | Median | Mean | U90%CI | St. Dev. |
|------|--------|--------|------|--------|----------|
| 2002 | 0.26   | 0.26   | 0.26 | 0.26   | 0.000    |
| 2003 | 0.24   | 0.25   | 0.25 | 0.25   | 0.000    |
| 2004 | 0.25   | 0.26   | 0.26 | 0.26   | 0.002    |
| 2005 | 0.26   | 0.26   | 0.26 | 0.26   | 0.000    |
| 2006 | 0.25   | 0.26   | 0.26 | 0.26   | 0.004    |
| 2007 | 0.24   | 0.26   | 0.26 | 0.26   | 0.009    |
| 2008 | 0.22   | 0.26   | 0.26 | 0.26   | 0.012    |
| 2009 | 0.22   | 0.26   | 0.25 | 0.26   | 0.014    |
| 2010 | 0.22   | 0.26   | 0.25 | 0.26   | 0.016    |
| 2011 | 0.22   | 0.26   | 0.25 | 0.26   | 0.016    |
| 2012 | 0.22   | 0.26   | 0.25 | 0.26   | 0.016    |
| 2013 | 0.22   | 0.26   | 0.25 | 0.26   | 0.016    |
| 2014 | 0.22   | 0.26   | 0.25 | 0.26   | 0.015    |

#### Catch Projections

| Year | L90%CI | Median | Mean  | U90%CI | St. Dev. |
|------|--------|--------|-------|--------|----------|
| 2002 | 223.5  | 223.5  | 223.5 | 223.5  | 0.00     |
| 2003 | 212.9  | 213.2  | 213.3 | 214.1  | 0.40     |
| 2004 | 242.0  | 248.7  | 250.4 | 265.2  | 7.32     |
| 2005 | 247.2  | 269.9  | 275.4 | 321.5  | 24.56    |
| 2006 | 217.4  | 270.8  | 276.8 | 352.0  | 43.63    |
| 2007 | 189.3  | 267.6  | 271.6 | 369.8  | 55.65    |
| 2008 | 172.6  | 264.6  | 267.9 | 368.4  | 61.33    |
| 2009 | 169.0  | 262.9  | 265.9 | 368.6  | 63.45    |
| 2010 | 161.0  | 263.9  | 264.6 | 377.1  | 64.16    |
| 2011 | 162.9  | 260.8  | 264.0 | 373.0  | 64.55    |
| 2012 | 165.5  | 262.1  | 264.7 | 372.2  | 64.48    |
| 2013 | 163.4  | 262.7  | 265.1 | 371.7  | 63.87    |
| 2014 | 165.5  | 262.5  | 265.8 | 378.0  | 63.27    |

Table 2.32—Equilibrium reference points and projections for BSAI Pacific cod spawning biomass (1000s of t), fishing mortality, and catch (1000s of t) under the assumption that  $F = \frac{1}{2} \max F_{ABC}$  in each year 2002–2014, where future recruitment is drawn from a distribution based on estimated recruitments spawned during the period 1977–2000. See Table 2.29 for symbol definitions.

| <b>Equilibrium Reference Points</b> |                  |                   |       |
|-------------------------------------|------------------|-------------------|-------|
| SPR                                 | Spawning Biomass | Fishing Mortality | Catch |
| 100%                                | 1,080            | 0                 | 0     |
| 40%                                 | 431              | 0.30              | 286   |
| 35%                                 | 377              | 0.36              | 305   |

| <b>Spawning Biomass Projections</b> |        |        |       |        |          |
|-------------------------------------|--------|--------|-------|--------|----------|
| Year                                | L90%CI | Median | Mean  | U90%CI | St. Dev. |
| 2002                                | 433.8  | 433.9  | 433.9 | 433.9  | 0.00     |
| 2003                                | 445.4  | 445.6  | 445.7 | 446.2  | 0.27     |
| 2004                                | 482.4  | 486.1  | 487.0 | 494.8  | 4.07     |
| 2005                                | 521.1  | 541.6  | 546.4 | 587.1  | 21.96    |
| 2006                                | 527.9  | 582.9  | 593.0 | 689.3  | 53.18    |
| 2007                                | 512.7  | 606.7  | 618.6 | 763.7  | 81.91    |
| 2008                                | 497.8  | 616.5  | 632.0 | 810.4  | 101.31   |
| 2009                                | 485.5  | 622.8  | 638.0 | 829.4  | 112.42   |
| 2010                                | 473.6  | 627.3  | 640.5 | 843.2  | 117.95   |
| 2011                                | 471.2  | 629.9  | 641.8 | 864.0  | 120.82   |
| 2012                                | 470.6  | 629.0  | 642.9 | 864.2  | 122.24   |
| 2013                                | 477.2  | 629.0  | 643.2 | 857.3  | 122.40   |
| 2014                                | 476.8  | 630.1  | 643.8 | 858.3  | 121.38   |

| <b>Fishing Mortality Projections</b> |        |        |      |        |          |
|--------------------------------------|--------|--------|------|--------|----------|
| Year                                 | L90%CI | Median | Mean | U90%CI | St. Dev. |
| 2002                                 | 0.15   | 0.15   | 0.15 | 0.15   | 0.000    |
| 2003                                 | 0.15   | 0.15   | 0.15 | 0.15   | 0.000    |
| 2004                                 | 0.15   | 0.15   | 0.15 | 0.15   | 0.000    |
| 2005                                 | 0.15   | 0.15   | 0.15 | 0.15   | 0.000    |
| 2006                                 | 0.15   | 0.15   | 0.15 | 0.15   | 0.000    |
| 2007                                 | 0.15   | 0.15   | 0.15 | 0.15   | 0.000    |
| 2008                                 | 0.15   | 0.15   | 0.15 | 0.15   | 0.000    |
| 2009                                 | 0.15   | 0.15   | 0.15 | 0.15   | 0.001    |
| 2010                                 | 0.15   | 0.15   | 0.15 | 0.15   | 0.002    |
| 2011                                 | 0.15   | 0.15   | 0.15 | 0.15   | 0.002    |
| 2012                                 | 0.15   | 0.15   | 0.15 | 0.15   | 0.002    |
| 2013                                 | 0.15   | 0.15   | 0.15 | 0.15   | 0.002    |
| 2014                                 | 0.15   | 0.15   | 0.15 | 0.15   | 0.002    |

| <b>Catch Projections</b> |        |        |       |        |          |
|--------------------------|--------|--------|-------|--------|----------|
| Year                     | L90%CI | Median | Mean  | U90%CI | St. Dev. |
| 2002                     | 133.5  | 133.5  | 133.5 | 133.5  | 0.00     |
| 2003                     | 143.8  | 143.9  | 144.0 | 144.3  | 0.17     |
| 2004                     | 163.4  | 166.3  | 167.0 | 173.2  | 3.21     |
| 2005                     | 169.3  | 183.1  | 186.5 | 213.9  | 14.88    |
| 2006                     | 160.6  | 190.0  | 194.4 | 242.1  | 26.84    |
| 2007                     | 151.8  | 191.6  | 196.6 | 260.3  | 34.14    |
| 2008                     | 146.0  | 192.7  | 197.6 | 262.2  | 37.86    |
| 2009                     | 144.4  | 192.9  | 198.1 | 263.7  | 39.46    |
| 2010                     | 141.0  | 194.6  | 198.1 | 273.1  | 40.15    |
| 2011                     | 142.1  | 192.8  | 198.1 | 273.3  | 40.74    |
| 2012                     | 143.3  | 193.1  | 198.6 | 269.0  | 40.87    |
| 2013                     | 143.0  | 194.4  | 198.8 | 269.7  | 40.66    |
| 2014                     | 143.6  | 195.0  | 199.1 | 274.4  | 40.24    |

Table 2.33—Equilibrium reference points and projections for BSAI Pacific cod spawning biomass (1000s of t), fishing mortality, and catch (1000s of t) under the assumption that  $F$  = the 1996-2000 average in each year 2002-2014, where future recruitment is drawn from a distribution based on estimated recruitments spawned during the period 1977-2000. See Table 2.29 for symbol definitions.

| <b>Equilibrium Reference Points</b> |                  |                   |       |
|-------------------------------------|------------------|-------------------|-------|
| SPR                                 | Spawning Biomass | Fishing Mortality | Catch |
| 100%                                | 1,080            | 0                 | 0     |
| 40%                                 | 431              | 0.30              | 286   |
| 35%                                 | 377              | 0.36              | 305   |

| <b>Spawning Biomass Projections</b> |        |        |       |        |          |
|-------------------------------------|--------|--------|-------|--------|----------|
| Year                                | L90%CI | Median | Mean  | U90%CI | St. Dev. |
| 2002                                | 431.5  | 431.5  | 431.5 | 431.5  | 0.00     |
| 2003                                | 430.1  | 430.4  | 430.4 | 430.9  | 0.27     |
| 2004                                | 456.5  | 460.1  | 461.0 | 468.8  | 4.07     |
| 2005                                | 484.8  | 505.1  | 509.8 | 550.1  | 21.75    |
| 2006                                | 482.6  | 536.0  | 545.9 | 639.2  | 51.70    |
| 2007                                | 462.3  | 551.9  | 563.1 | 702.3  | 78.02    |
| 2008                                | 444.4  | 556.1  | 570.5 | 738.3  | 94.92    |
| 2009                                | 430.7  | 558.5  | 572.8 | 749.6  | 104.13   |
| 2010                                | 419.9  | 562.1  | 573.0 | 765.9  | 108.43   |
| 2011                                | 416.7  | 561.2  | 572.8 | 776.8  | 110.61   |
| 2012                                | 415.2  | 561.2  | 573.0 | 774.3  | 111.69   |
| 2013                                | 420.1  | 560.3  | 572.9 | 765.1  | 111.69   |
| 2014                                | 418.3  | 560.1  | 573.2 | 769.6  | 110.68   |

| <b>Fishing Mortality Projections</b> |        |        |      |        |          |
|--------------------------------------|--------|--------|------|--------|----------|
| Year                                 | L90%CI | Median | Mean | U90%CI | St. Dev. |
| 2002                                 | 0.19   | 0.19   | 0.19 | 0.19   | 0.000    |
| 2003                                 | 0.19   | 0.19   | 0.19 | 0.19   | 0.000    |
| 2004                                 | 0.19   | 0.19   | 0.19 | 0.19   | 0.000    |
| 2005                                 | 0.19   | 0.19   | 0.19 | 0.19   | 0.000    |
| 2006                                 | 0.19   | 0.19   | 0.19 | 0.19   | 0.000    |
| 2007                                 | 0.19   | 0.19   | 0.19 | 0.19   | 0.000    |
| 2008                                 | 0.19   | 0.19   | 0.19 | 0.19   | 0.000    |
| 2009                                 | 0.19   | 0.19   | 0.19 | 0.19   | 0.000    |
| 2010                                 | 0.19   | 0.19   | 0.19 | 0.19   | 0.000    |
| 2011                                 | 0.19   | 0.19   | 0.19 | 0.19   | 0.000    |
| 2012                                 | 0.19   | 0.19   | 0.19 | 0.19   | 0.000    |
| 2013                                 | 0.19   | 0.19   | 0.19 | 0.19   | 0.000    |
| 2014                                 | 0.19   | 0.19   | 0.19 | 0.19   | 0.000    |

| <b>Catch Projections</b> |        |        |       |        |          |
|--------------------------|--------|--------|-------|--------|----------|
| Year                     | L90%CI | Median | Mean  | U90%CI | St. Dev. |
| 2002                     | 168.6  | 168.6  | 168.6 | 168.6  | 0.00     |
| 2003                     | 175.1  | 175.3  | 175.3 | 175.8  | 0.21     |
| 2004                     | 196.2  | 199.8  | 200.7 | 208.5  | 4.04     |
| 2005                     | 200.1  | 217.2  | 221.4 | 255.8  | 18.55    |
| 2006                     | 186.9  | 223.0  | 228.2 | 286.6  | 32.85    |
| 2007                     | 174.9  | 223.4  | 228.9 | 304.0  | 41.19    |
| 2008                     | 167.2  | 222.8  | 228.9 | 306.1  | 45.21    |
| 2009                     | 164.9  | 222.7  | 228.8 | 306.9  | 46.75    |
| 2010                     | 161.1  | 223.2  | 228.4 | 317.1  | 47.23    |
| 2011                     | 161.6  | 222.2  | 228.1 | 315.9  | 47.80    |
| 2012                     | 163.3  | 221.6  | 228.5 | 310.8  | 47.94    |
| 2013                     | 163.2  | 223.2  | 228.6 | 310.6  | 47.62    |
| 2014                     | 163.2  | 223.3  | 229.0 | 318.9  | 47.09    |

Table 2.34—Equilibrium reference points and projections for BSAI Pacific cod spawning biomass (1000s of t), fishing mortality, and catch (1000s of t) under the assumption that  $F = 0$  in each year 2002-2014, where future recruitment is drawn from a distribution based on estimated recruitments spawned during the period 1977-2000. See Table 2.29 for symbol definitions.

**Equilibrium Reference Points**

| SPR  | Spawning Biomass | Fishing Mortality | Catch |
|------|------------------|-------------------|-------|
| 100% | 1,080            | 0                 | 0     |
| 40%  | 431              | 0.30              | 286   |
| 35%  | 377              | 0.36              | 305   |

**Spawning Biomass Projections**

| Year | L90%CI | Median | Mean   | U90%CI | St. Dev. |
|------|--------|--------|--------|--------|----------|
| 2002 | 442.4  | 442.5  | 442.5  | 442.5  | 0.00     |
| 2003 | 505.3  | 505.5  | 505.6  | 506.1  | 0.27     |
| 2004 | 594.1  | 597.8  | 598.7  | 606.5  | 4.10     |
| 2005 | 687.9  | 709.1  | 714.0  | 756.3  | 22.77    |
| 2006 | 748.2  | 808.8  | 820.2  | 927.7  | 59.23    |
| 2007 | 772.5  | 884.5  | 899.8  | 1076.3 | 99.07    |
| 2008 | 781.7  | 936.4  | 956.7  | 1186.1 | 131.39   |
| 2009 | 785.2  | 972.5  | 994.0  | 1254.5 | 153.79   |
| 2010 | 783.3  | 996.8  | 1018.6 | 1307.4 | 167.84   |
| 2011 | 782.3  | 1018.5 | 1036.5 | 1356.1 | 176.48   |
| 2012 | 788.8  | 1028.5 | 1049.1 | 1381.8 | 181.63   |
| 2013 | 797.4  | 1035.1 | 1055.5 | 1386.4 | 184.14   |
| 2014 | 803.7  | 1046.1 | 1060.6 | 1381.2 | 184.09   |

**Fishing Mortality Projections**

| Year | L90%CI | Median | Mean | U90%CI | St. Dev. |
|------|--------|--------|------|--------|----------|
| 2002 | 0      | 0      | 0    | 0      | 0        |
| 2003 | 0      | 0      | 0    | 0      | 0        |
| 2004 | 0      | 0      | 0    | 0      | 0        |
| 2005 | 0      | 0      | 0    | 0      | 0        |
| 2006 | 0      | 0      | 0    | 0      | 0        |
| 2007 | 0      | 0      | 0    | 0      | 0        |
| 2008 | 0      | 0      | 0    | 0      | 0        |
| 2009 | 0      | 0      | 0    | 0      | 0        |
| 2010 | 0      | 0      | 0    | 0      | 0        |
| 2011 | 0      | 0      | 0    | 0      | 0        |
| 2012 | 0      | 0      | 0    | 0      | 0        |
| 2013 | 0      | 0      | 0    | 0      | 0        |
| 2014 | 0      | 0      | 0    | 0      | 0        |

**Catch Projections**

| Year | L90%CI | Median | Mean | U90%CI | St. Dev. |
|------|--------|--------|------|--------|----------|
| 2002 | 0      | 0      | 0    | 0      | 0        |
| 2003 | 0      | 0      | 0    | 0      | 0        |
| 2004 | 0      | 0      | 0    | 0      | 0        |
| 2005 | 0      | 0      | 0    | 0      | 0        |
| 2006 | 0      | 0      | 0    | 0      | 0        |
| 2007 | 0      | 0      | 0    | 0      | 0        |
| 2008 | 0      | 0      | 0    | 0      | 0        |
| 2009 | 0      | 0      | 0    | 0      | 0        |
| 2010 | 0      | 0      | 0    | 0      | 0        |
| 2011 | 0      | 0      | 0    | 0      | 0        |
| 2012 | 0      | 0      | 0    | 0      | 0        |
| 2013 | 0      | 0      | 0    | 0      | 0        |
| 2014 | 0      | 0      | 0    | 0      | 0        |

Table 2.35—Equilibrium reference points and projections for BSAI Pacific cod spawning biomass (1000s of t), fishing mortality, and catch (1000s of t) under the assumption that  $F = F_{OFL}$  in each year 2002-2014, where future recruitment is drawn from a distribution based on estimated recruitments spawned during the period 1977-2000. See Table 2.29 for symbol definitions.

**Equilibrium Reference Points**

| SPR  | Spawning Biomass | Fishing Mortality | Catch |
|------|------------------|-------------------|-------|
| 100% | 1,080            | 0                 | 0     |
| 40%  | 431              | 0.30              | 286   |
| 35%  | 377              | 0.36              | 305   |

**Spawning Biomass Projections**

| Year | L90%CI | Median | Mean  | U90%CI | St. Dev. |
|------|--------|--------|-------|--------|----------|
| 2002 | 422.4  | 422.4  | 422.4 | 422.4  | 0.00     |
| 2003 | 378.2  | 378.4  | 378.5 | 379.0  | 0.26     |
| 2004 | 380.4  | 383.8  | 384.7 | 392.0  | 3.82     |
| 2005 | 386.2  | 404.2  | 408.5 | 444.6  | 19.49    |
| 2006 | 366.0  | 408.5  | 416.2 | 491.8  | 41.75    |
| 2007 | 341.1  | 402.1  | 412.1 | 518.0  | 57.23    |
| 2008 | 325.4  | 396.6  | 407.6 | 524.8  | 64.46    |
| 2009 | 318.8  | 392.5  | 404.8 | 520.2  | 66.91    |
| 2010 | 314.0  | 395.0  | 403.4 | 528.3  | 66.97    |
| 2011 | 315.8  | 391.1  | 402.6 | 531.9  | 66.91    |
| 2012 | 317.2  | 392.2  | 403.0 | 528.4  | 67.11    |
| 2013 | 315.1  | 391.8  | 403.5 | 525.3  | 67.09    |
| 2014 | 317.2  | 392.1  | 404.1 | 532.3  | 66.26    |

**Fishing Mortality Projections**

| Year | L90%CI | Median | Mean | U90%CI | St. Dev. |
|------|--------|--------|------|--------|----------|
| 2002 | 0.35   | 0.35   | 0.35 | 0.35   | 0.000    |
| 2003 | 0.31   | 0.31   | 0.31 | 0.31   | 0.000    |
| 2004 | 0.31   | 0.32   | 0.32 | 0.32   | 0.003    |
| 2005 | 0.32   | 0.33   | 0.34 | 0.36   | 0.012    |
| 2006 | 0.30   | 0.34   | 0.34 | 0.36   | 0.020    |
| 2007 | 0.28   | 0.33   | 0.33 | 0.36   | 0.027    |
| 2008 | 0.27   | 0.33   | 0.32 | 0.36   | 0.032    |
| 2009 | 0.26   | 0.32   | 0.32 | 0.36   | 0.034    |
| 2010 | 0.26   | 0.33   | 0.32 | 0.36   | 0.035    |
| 2011 | 0.26   | 0.32   | 0.32 | 0.36   | 0.035    |
| 2012 | 0.26   | 0.32   | 0.32 | 0.36   | 0.035    |
| 2013 | 0.26   | 0.32   | 0.32 | 0.36   | 0.034    |
| 2014 | 0.26   | 0.32   | 0.32 | 0.36   | 0.034    |

**Catch Projections**

| Year | L90%CI | Median | Mean  | U90%CI | St. Dev. |
|------|--------|--------|-------|--------|----------|
| 2002 | 293.8  | 293.8  | 293.8 | 293.9  | 0.00     |
| 2003 | 251.0  | 251.4  | 251.5 | 252.5  | 0.51     |
| 2004 | 273.3  | 281.6  | 283.7 | 301.8  | 9.43     |
| 2005 | 271.0  | 310.7  | 320.2 | 397.5  | 41.13    |
| 2006 | 230.0  | 309.6  | 316.8 | 425.0  | 64.00    |
| 2007 | 198.0  | 296.8  | 304.1 | 438.3  | 76.24    |
| 2008 | 181.0  | 286.5  | 296.9 | 430.1  | 81.85    |
| 2009 | 172.1  | 282.5  | 293.4 | 433.6  | 83.27    |
| 2010 | 170.6  | 285.6  | 292.2 | 435.4  | 83.46    |
| 2011 | 172.4  | 279.4  | 291.3 | 437.3  | 83.70    |
| 2012 | 172.3  | 283.3  | 292.4 | 436.5  | 83.60    |
| 2013 | 172.7  | 282.7  | 293.0 | 434.7  | 83.16    |
| 2014 | 174.3  | 282.4  | 294.2 | 437.2  | 82.72    |

Table 2.36—Equilibrium reference points and projections for BSAI Pacific cod spawning biomass (1000s of t), fishing mortality, and catch (1000s of t) under the assumption that  $F = \max F_{ABC}$  in each year 2002-2003 and  $F = F_{OFL}$  thereafter, where future recruitment is drawn from a distribution based on estimated recruitments spawned during the period 1977-2000. See Table 2.29 for symbol definitions.

**Equilibrium Reference Points**

| SPR  | Spawning Biomass | Fishing Mortality | Catch |
|------|------------------|-------------------|-------|
| 100% | 1,080            | 0                 | 0     |
| 40%  | 431              | 0.30              | 286   |
| 35%  | 377              | 0.36              | 305   |

**Spawning Biomass Projections**

| Year | L90%CI | Median | Mean  | U90%CI | St. Dev. |
|------|--------|--------|-------|--------|----------|
| 2002 | 425.4  | 425.4  | 425.4 | 425.4  | 0.00     |
| 2003 | 394.6  | 394.8  | 394.9 | 395.4  | 0.26     |
| 2004 | 400.1  | 403.6  | 404.4 | 411.7  | 3.82     |
| 2005 | 396.1  | 414.1  | 418.5 | 454.8  | 19.55    |
| 2006 | 370.0  | 412.3  | 420.3 | 497.9  | 42.30    |
| 2007 | 342.1  | 403.1  | 413.6 | 520.9  | 57.77    |
| 2008 | 325.6  | 396.7  | 408.0 | 526.1  | 64.78    |
| 2009 | 318.8  | 392.6  | 404.8 | 520.5  | 67.05    |
| 2010 | 313.8  | 394.8  | 403.3 | 528.4  | 67.02    |
| 2011 | 315.7  | 391.2  | 402.6 | 532.1  | 66.92    |
| 2012 | 317.1  | 392.2  | 402.9 | 528.4  | 67.12    |
| 2013 | 315.1  | 391.8  | 403.5 | 525.3  | 67.09    |
| 2014 | 317.2  | 392.1  | 404.1 | 532.3  | 66.26    |

**Fishing Mortality Projections**

| Year | L90%CI | Median | Mean | U90%CI | St. Dev. |
|------|--------|--------|------|--------|----------|
| 2002 | 0.30   | 0.30   | 0.30 | 0.30   | 0.000    |
| 2003 | 0.27   | 0.27   | 0.27 | 0.27   | 0.000    |
| 2004 | 0.33   | 0.33   | 0.33 | 0.34   | 0.003    |
| 2005 | 0.33   | 0.34   | 0.34 | 0.36   | 0.010    |
| 2006 | 0.30   | 0.34   | 0.34 | 0.36   | 0.019    |
| 2007 | 0.28   | 0.33   | 0.33 | 0.36   | 0.027    |
| 2008 | 0.27   | 0.33   | 0.32 | 0.36   | 0.032    |
| 2009 | 0.26   | 0.32   | 0.32 | 0.36   | 0.034    |
| 2010 | 0.26   | 0.33   | 0.32 | 0.36   | 0.035    |
| 2011 | 0.26   | 0.32   | 0.32 | 0.36   | 0.035    |
| 2012 | 0.26   | 0.32   | 0.32 | 0.36   | 0.035    |
| 2013 | 0.26   | 0.32   | 0.32 | 0.36   | 0.034    |
| 2014 | 0.26   | 0.32   | 0.32 | 0.36   | 0.034    |

**Catch Projections**

| Year | L90%CI | Median | Mean  | U90%CI | St. Dev. |
|------|--------|--------|-------|--------|----------|
| 2002 | 253.5  | 253.5  | 253.5 | 253.5  | 0.00     |
| 2003 | 230.5  | 230.9  | 231.0 | 231.8  | 0.45     |
| 2004 | 298.4  | 307.1  | 309.4 | 328.3  | 9.86     |
| 2005 | 282.3  | 322.7  | 331.0 | 402.4  | 39.40    |
| 2006 | 233.6  | 313.4  | 320.0 | 427.6  | 63.45    |
| 2007 | 198.7  | 297.2  | 304.8 | 439.6  | 76.27    |
| 2008 | 180.9  | 286.1  | 296.9 | 430.2  | 81.94    |
| 2009 | 171.9  | 282.2  | 293.3 | 433.7  | 83.32    |
| 2010 | 170.4  | 285.4  | 292.1 | 435.2  | 83.49    |
| 2011 | 172.3  | 279.3  | 291.2 | 437.4  | 83.72    |
| 2012 | 172.2  | 283.3  | 292.3 | 436.5  | 83.61    |
| 2013 | 172.7  | 282.7  | 293.0 | 434.7  | 83.16    |
| 2014 | 174.3  | 282.4  | 294.2 | 437.2  | 82.72    |

Table 2.37--Summary of major results for the stock assessment of Pacific cod in the BSAI region.

|                                |                                    |              |
|--------------------------------|------------------------------------|--------------|
| Natural mortality rate:        |                                    | 0.37         |
| Reference fishing mortalities: | <u>Rate</u>                        | <u>Value</u> |
|                                | $F_{35\%}$                         | 0.36         |
|                                | $F_{40\%}$                         | 0.30         |
|                                | $\max F_{ABC}$                     | 0.30         |
| Equilibrium spawning biomass:  | <u>Region and type</u>             | <u>Value</u> |
|                                | EBS $B_{35\%}$                     | 322,000 t    |
|                                | EBS $B_{40\%}$                     | 368,000 t    |
|                                | BSAI $B_{35\%}$                    | 377,000 t    |
|                                | BSAI $B_{40\%}$                    | 431,000 t    |
| Projected biomass for 2002:    | <u>Region and type</u>             | <u>Value</u> |
|                                | EBS Age 3+                         | 1,320,000 t  |
|                                | EBS Spawning (at $\max F_{ABC}$ )  | 363,000 t    |
|                                | BSAI Age 3+                        | 1,540,000 t  |
|                                | BSAI Spawning (at $\max F_{ABC}$ ) | 425,000 t    |
| Recommended ABC for 2002:      | <u>Units</u>                       | <u>Value</u> |
|                                | Fishing Mortality                  | 0.26         |
|                                | EBS Catch                          | 191,000 t    |
|                                | BSAI Catch                         | 223,000 t    |
| Overfishing level for 2002:    | <u>Units</u>                       | <u>Value</u> |
|                                | Fishing Mortality                  | 0.35         |
|                                | EBS Catch                          | 251,000 t    |
|                                | BSAI Catch                         | 294,000 t    |

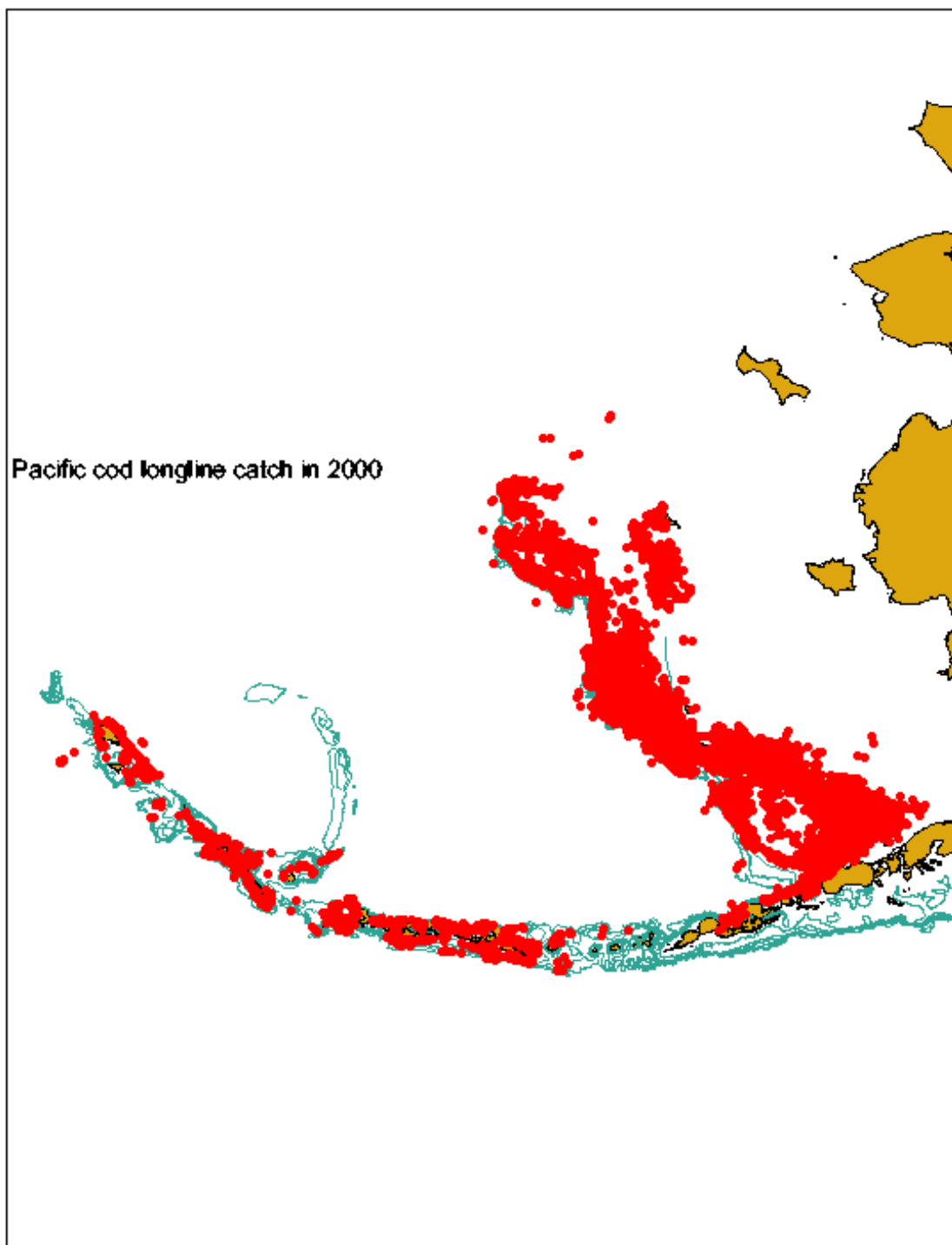


Figure 2.1—Observed fishing locations in the 2000 trawl fisheries for Pacific cod in the BSAI.

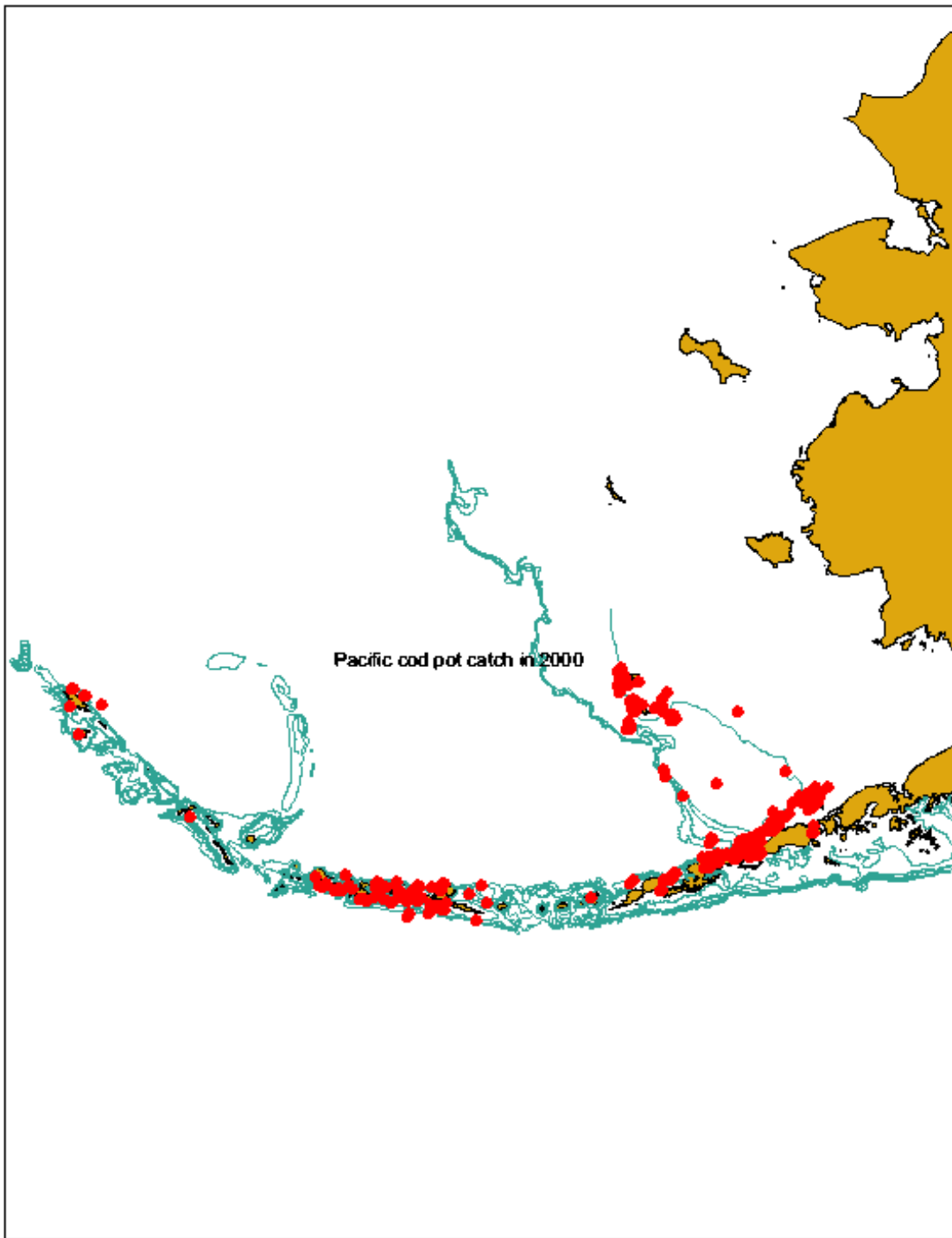
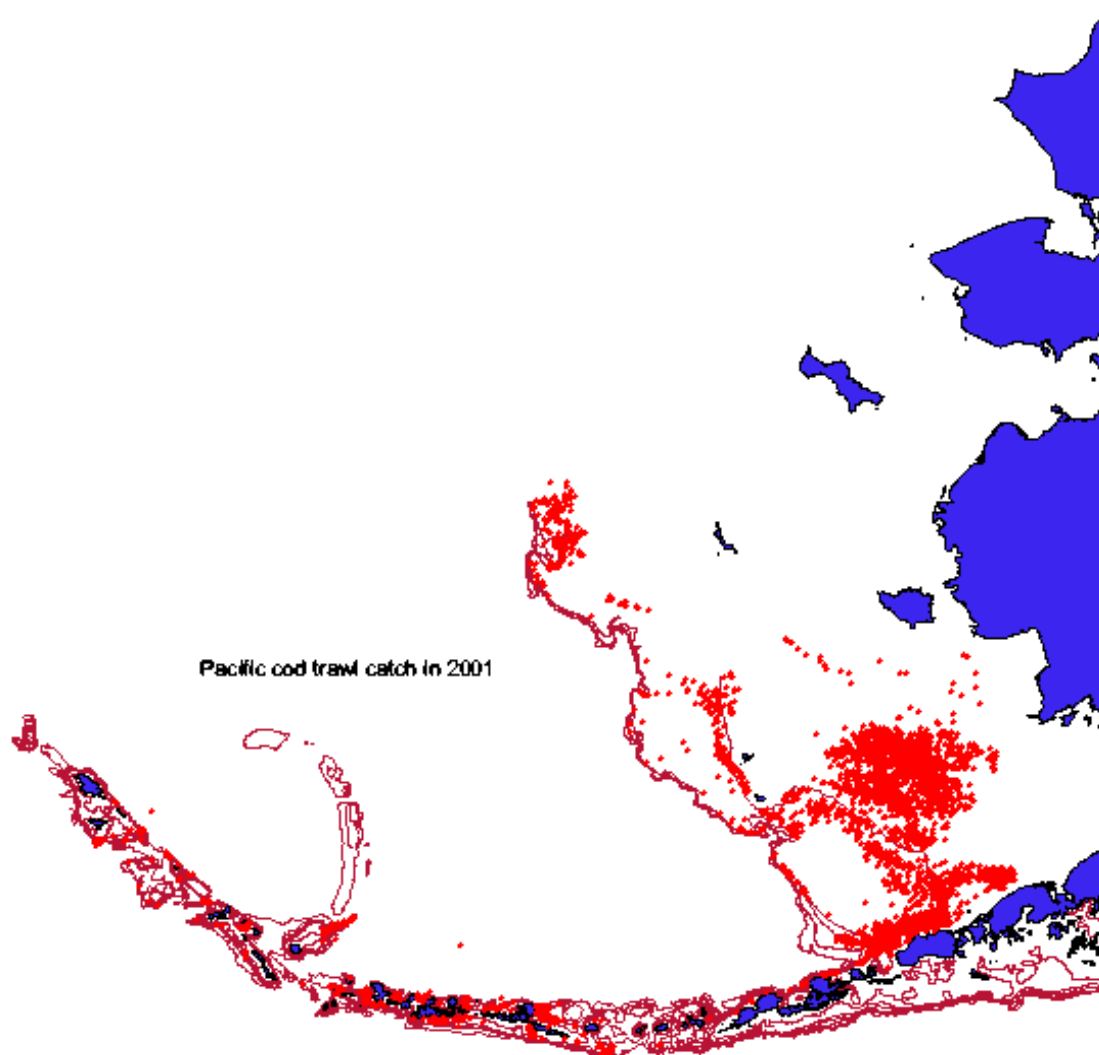


Figure  
2.2—Obs  
erved

fishing locations in the 2000 longline fisheries for Pacific cod in the BSAI.



fishing locations in the 2000 pot fisheries for Pacific cod in the BSAI.

Figure  
2.3—Obs  
erved

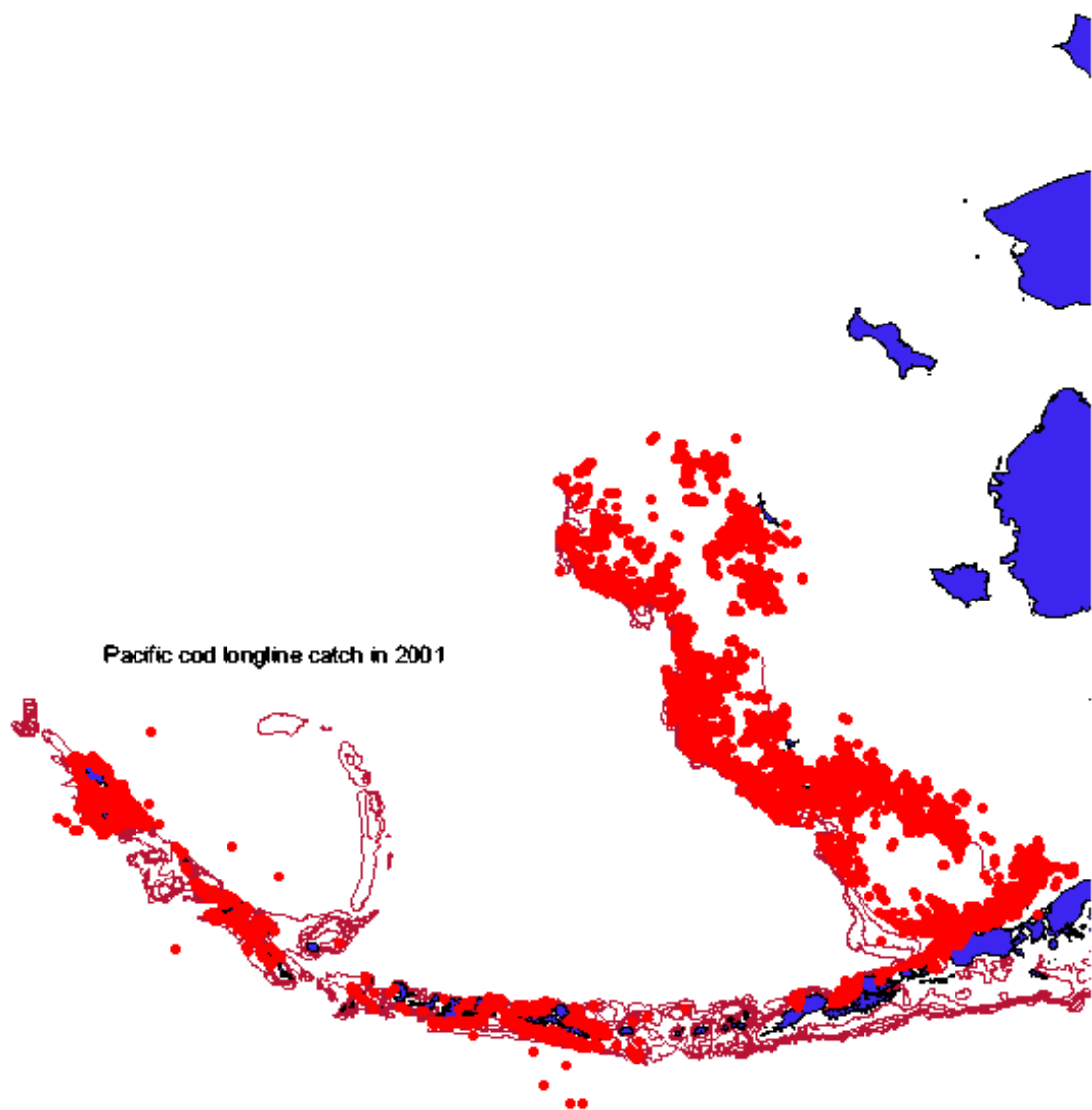
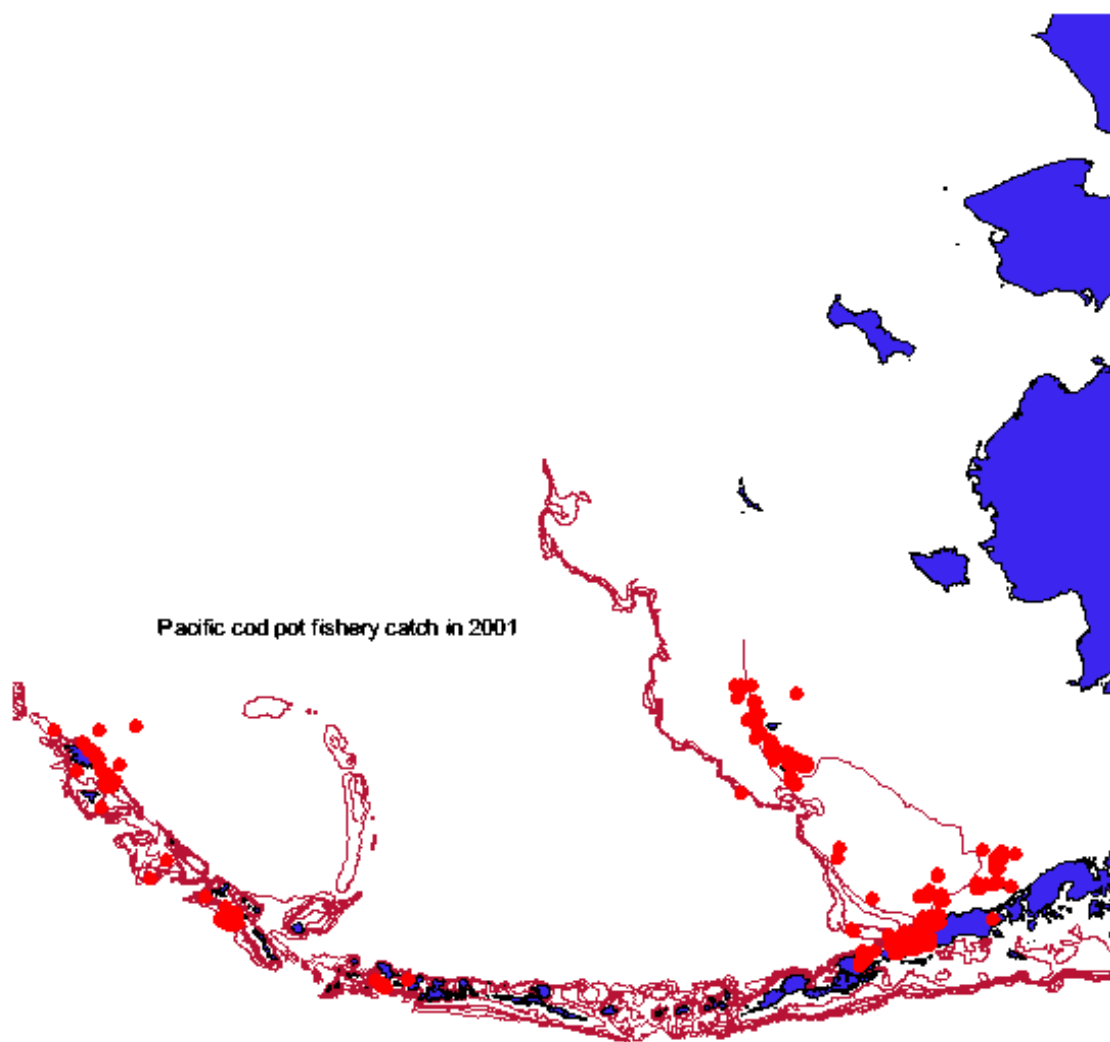


Figure 2.4—Observed fishing locations in the 2001 trawl fisheries for Pacific cod in the BSAI.



fishing locations in the 2001 longline fisheries for Pacific cod in the BSAI.

Figure  
2.5—Obs  
erved

Figure 2.6—Observed fishing locations in the 2001 pot fisheries for Pacific cod in the BSAI.

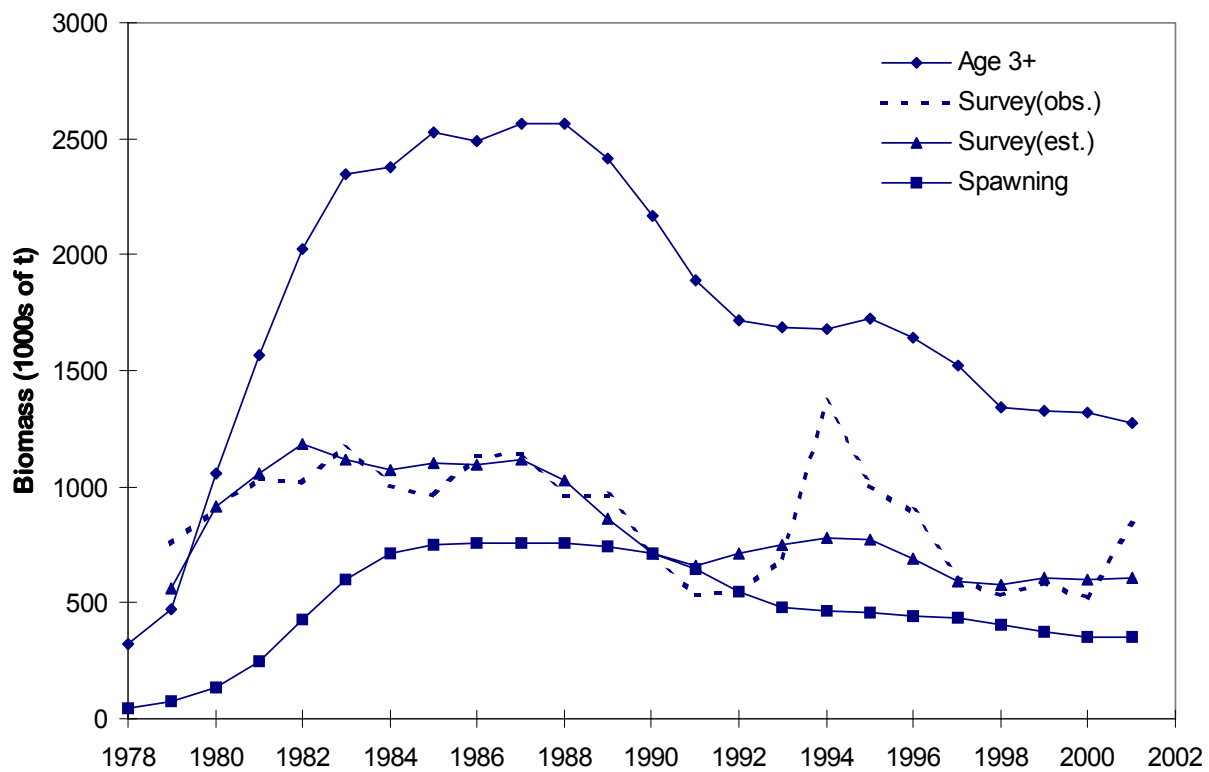
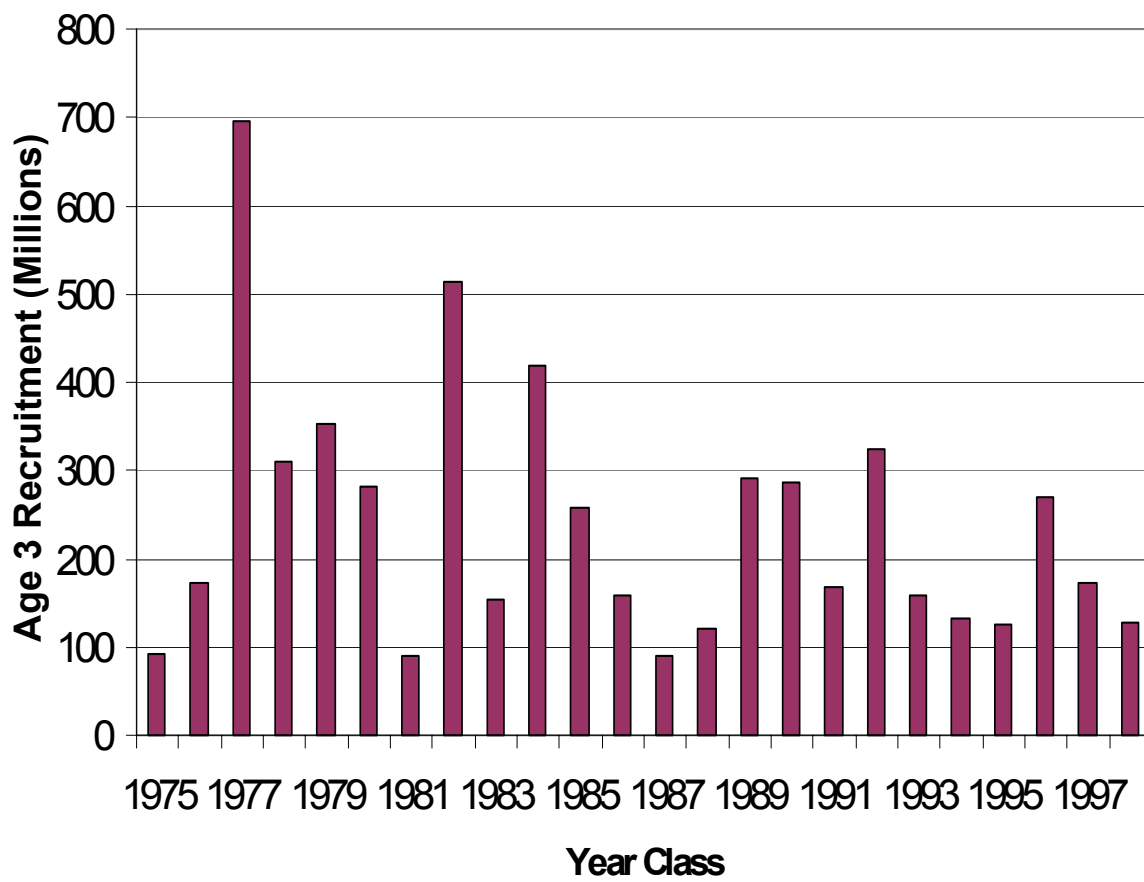


Figure 2.7—Three Pacific cod biomass time series (EBS only) estimated by the stock assessment model, together with the time series of biomass levels observed by the survey.

Figure 2.8–Pacific cod recruitment at age 3 (EBS only) as estimated by the stock assessment model.



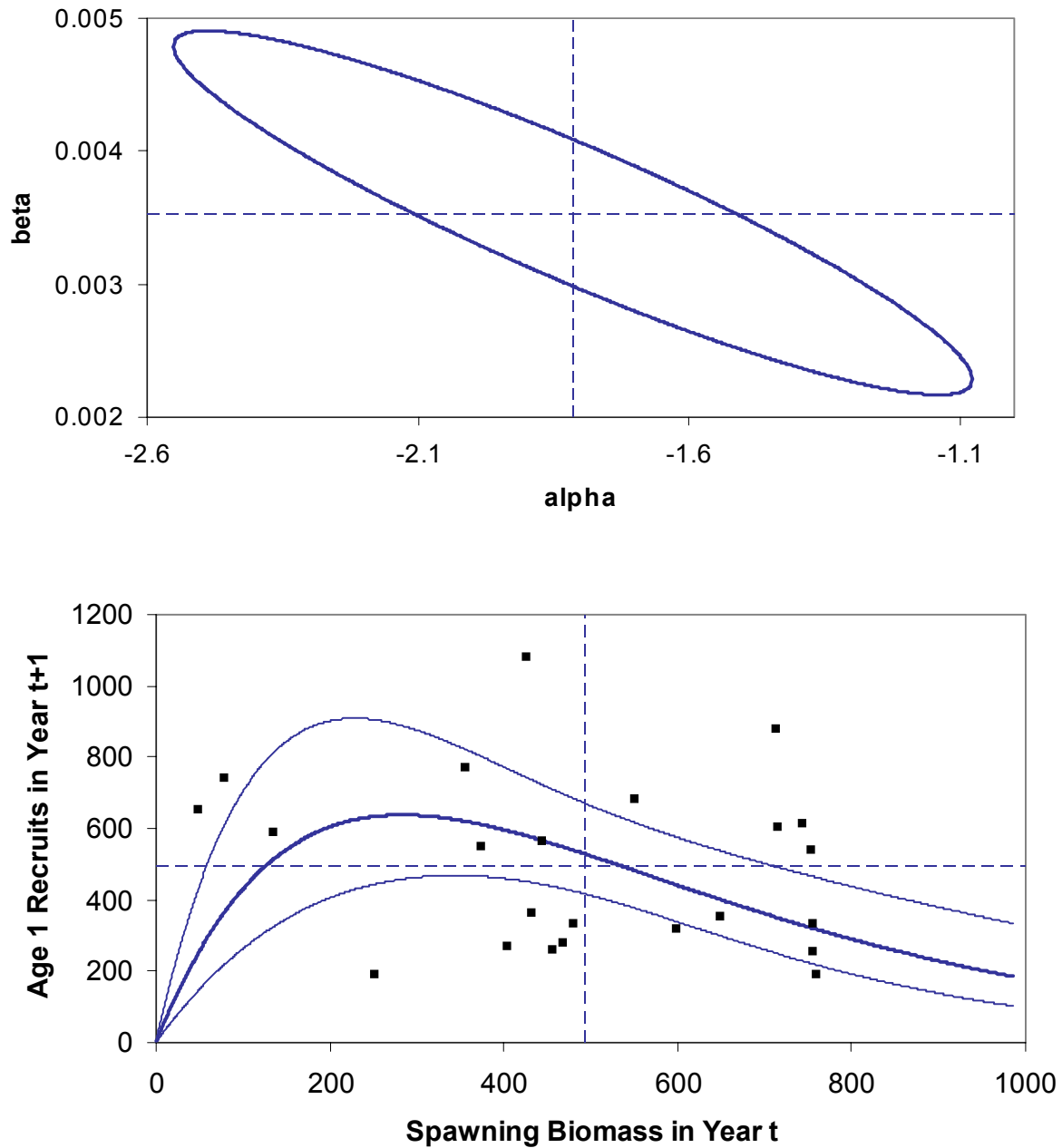


Figure 2.9—Some aspects of uncertainty surrounding the stock-recruitment relationship. The upper panel shows a 95% confidence ellipse for the estimated parameters of the stock-recruitment relationship, with dashed lines indicating the location of the point estimates. The lower panel shows the data (small squares), the estimated relationship (bold curve), and the 95% confidence interval around the curve (thin curves), with dashed lines indicating the locations of the data means. See text for details and caveats.

## Appendix 2A: Approximate Functional Representations of Population Dynamics Used in Synthesis

These equations are similar to those used in Synthesis. Symbols are defined in Table 2.14.

### Functions of Length or Age

Weight at length:

$$w(\lambda) = W_1 \lambda^{W_2}$$

Proportion mature at length:

$$p(\lambda) = \frac{1}{1 + \exp(-P_1(P_2 - \lambda))}$$

Length at age:

$$l(\alpha) = L_1 + (L_2 - L_1) \left( \frac{1 - \exp(-K(\alpha - \alpha_1))}{1 - \exp(-K(\alpha_2 - \alpha_1))} \right)$$

Standard deviation of length at age:

$$x(\alpha) = X_1 + (X_2 - X_1) \left( \frac{l(\alpha) - L_1}{L_2 - L_1} \right)$$

Probability density function describing distribution of length, conditional on age:

$$h(\lambda | \alpha) = \sqrt{\frac{1}{2\pi}} \left( \frac{1}{x(\alpha)} \right) \exp \left( - \left( \frac{1}{2} \right) \left( \frac{\lambda - l(\alpha)}{x(\alpha)} \right)^2 \right)$$

Selectivity at length  $\lambda \leq S_{g,4,e(y|g)}$  (ascending limb), conditional on gear type and year:

$$s(\lambda | g, y) = S_{g,1,e(y|g)} + (1 - S_{g,1,e(y|g)}) \left( \frac{\frac{1}{1 + \exp(-S_{g,3,e(y|g)}(\lambda - S_{g,2,e(y|g)}))} - \frac{1}{1 + \exp(-S_{g,3,e(y|g)}(\lambda_{min} - S_{g,2,e(y|g)}))}}{\frac{1}{1 + \exp(-S_{g,3,e(y|g)}(S_{g,4,e(y|g)} - S_{g,2,e(y|g)}))} - \frac{1}{1 + \exp(-S_{g,3,e(y|g)}(\lambda_{min} - S_{g,2,e(y|g)}))}} \right)$$

Selectivity at length  $\lambda \geq S_{g,4,e(y|g)}$  (descending limb), conditional on gear type and year:

$$s(\lambda|g,y) = 1 +$$

$$(1 - S_{g,5,e(y|g)}) \left( \frac{\frac{1}{1 + \exp(-S_{g,7,e(y|g)}(\lambda - S_{g,6,e(y|g)}))} - \frac{1}{1 + \exp(-S_{g,7,e(y|g)}(S_{g,4} - S_{g,6,e(y|g)}))}}{\frac{1}{1 + \exp(-S_{g,7,e(y|g)}(\lambda_{max} - S_{g,6,e(y|g)}))} - \frac{1}{1 + \exp(-S_{g,7,e(y|g)}(S_{g,4,e(y|g)} - S_{g,6,e(y|g)}))}} \right)$$

### Numbers at Age

Matrix for converting numbers at length into numbers at age:

$$z_{a,i,j} = \frac{\int_{l_{min}(j)}^{l_{min}(j+1)} h(\lambda | a + t_{dur}(i)) d\lambda}{\int_{\lambda_{min}}^{\lambda_{max}} h(\lambda | a + t_{dur}(i)) d\lambda}$$

For all  $y$  :

$$n_{a_{min},y,1} = R_y$$

For all  $a > a_{min}$  :

$$n_{a,1,1} = N_a$$

For all  $i < i_{max}$  :

$$n_{a,y,i+1} = n_{a,y,i} \sum_{j=1}^{j_{max}} \left( z_{a,i,j} \exp \left( \left( -M - \sum_{g=1}^{g_{max}} F_{g,y,i} s(l_{mid}(j)|g,y) \right) t_{dur}(i) \right) \right)$$

For all  $a < a_{max}$  and all  $y < y_{max}$  :

$$n_{a+1,y+1,1} = n_{a,y,i_{max}} \sum_{j=1}^{j_{max}} \left( z_{a,i_{max},j} \exp \left( \left( -M - \sum_{g=1}^{g_{max}} F_{g,y,i_{max}} s(l_{mid}(j)|g,y) \right) t_{dur}(i_{max}) \right) \right)$$

For all  $y < y_{max}$  :

$$n_{a_{max}, y+1, 1} = n_{a_{max}-1, y, i_{max}} \sum_{j=1}^{j_{max}} \left( z_{a_{max}-1, i_{max}, j} \exp \left( \left( -M - \sum_{g=1}^{g_{max}} F_{g, y, i_{max}} s(l_{mid}(j) | g, y) \right) t_{dur}(i_{max}) \right) \right) \\ + n_{a_{max}, y, i_{max}} \sum_{j=1}^{j_{max}} \left( z_{a_{max}, i_{max}, j} \exp \left( \left( -M - \sum_{g=1}^{g_{max}} F_{g, y, i_{max}} s(l_{mid}(j) | g, y) \right) t_{dur}(i_{max}) \right) \right)$$

At time of spawning:

$$u_{a, y} = n_{a, y, i_{spa}} \sum_{j=1}^{j_{max}} \left( z_{a, i_{spa}, j} \exp \left( \left( -M - \sum_{g=1}^{g_{max}} F_{g, y, i_{spa}} s(l_{mid}(j) | g, y) \right) \left( \tau_{spa} - \sum_{i=1}^{i_{spa}-1} t_{dur}(i) \right) \right) \right)$$

At time of survey:

$$v_{a, y} = n_{a, y, i_{sur}} \sum_{j=1}^{j_{max}} \left( z_{a, i_{sur}, j} \exp \left( \left( -M - \sum_{g=1}^{g_{max}} F_{g, y, i_{sur}} s(l_{mid}(j) | g, y) \right) \left( \tau_{sur} - \sum_{i=1}^{i_{sur}-1} t_{dur}(i) \right) \right) \right)$$

### Biomass

Start-of-year biomass at ages  $a > a_{rec}$  :

$$b_y = \sum_{a=a_{rec}}^{a_{max}} \left( n_{a, y, 1} \sum_{j=1}^{j_{max}} z_{a, 1, j} w(l_{mid}(j)) \right)$$

Female spawning biomass:

$$c_y = \frac{1}{2} \sum_{a=a_{min}}^{a_{max}} \left( u_{a, y} \sum_{j=1}^{j_{max}} z_{a, i_{spa}, j} w(l_{mid}(j)) p(l_{mid}(j)) \right)$$

Survey biomass:

$$d_y = Q \sum_{a=a_{min}}^{a_{max}} \left( v_{a, y} \sum_{j=1}^{j_{max}} z_{a, i_{sur}, j} w(l_{mid}(j)) s(l_{mid}(j) | g_{sur}, y) \right)$$